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CHEMICAL TREATMENT FOR GUAVA WILT

By

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Introduction:

Garrett (1944) listed a number of soil-borne plant diseases which were favoured by acidic or alkaline soils. Mehta (1951) reported severe wilting of guava (*Psidium guajava* L.), caused by *Fusarium oxysporum* f. *psidii* in the alkaline soils of Allahabad with hydrogen-ion-concentration ranging from 7·5 to 9·0. As a soil acidifying agent, sulphur is known to reduce potato scab (Duff and Welch, 1927), tobacco root-rot (Anderson and Morgan, 1926) and Texas root-rot of cotton (Taubenhaus and Ezekiel, 1947). The application of lime increases the alkalinity of the soil and is known to check the severity of club-root of crucifers in acidic soils (Bennett, 1939).

In the present paper the effect of the hydrogen-ion-concentration on the growth of *Fusarium oxysporum* f. *psidii* in Richard's medium and the effect of the application of a few acidifying and alkaline agents to the soil in reducing guava wilt at Allahabad and Lucknow have been discussed.

Method and Materials :

In order to study the effect of pH on the growth of *Fusarium oxysporum* f. *psidii*, aliquots of the modified Richards's solution (KNO_3, 10·00 gm., KH_2PO_4, 5·00 gm., $MgSO_4$. $7H_2O$, 2·50 gm., $FeCl_3$, 0·02 gm., Sucrose, 50·00 gm. and distilled water, 1000·00 cc.) were adjusted to pH values ranging from 1·5 to 8·6. Conical flasks containing 50 cc. of the medium were inoculated with a virulent strain of the pathogen and incubated at 25°C for 60 days. Then the dry weight of mycelial mats obtained under different treatments, in triplicate, were determined.

As regards field trials, 112 guava trees with symptoms of mild wilting were selected in October, 1953, at the Minto Park, Allahabad with a soil pH of 7·9.

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About the same time, 96 more guava trees aged 10–12 years showing mild wilting were selected at the National Botanic Gardens, Lucknow with a soil pH of 7·7. The trees were divided into four groups. One group was not given any treatment to serve as check and the roots of trees of the other three groups were exposed to a depth of about 6" and the soil was mixed thoroughly at the rate of 4 lbs. sulphur, molasses and lime per tree. These trees were again treated in the same manner in January, 1955. Another set of field experiments was laid out in November, 1957, at the Minto Park ; Sallahpur and Pryag Vidyapeeth, Allahabad where 16–20 year old guava trees were divided into groups of 30, 50 and 20 trees respectively, These trees also showed symptoms of mild wilting. In the root region the soil with pH 7·2 was mixed only once with lime or gypsum at the rate of 4 lbs. per tree. No chemical was applied to the remaining trees which served as checks. Final observation were taken in January, 1961. Thus the field experiments started at the National Botanical Gardens, Lucknow and Minto Park, Allahabad were concluded after taking repeated observations for eight years (1953–61). The experiments conducted at Minto Park, Sallahpur and Pryag Vidyapeeth, Allahabad were similarly concluded after four years (1957–61).

Observations :

The growth of the pathogen varied at different pH values of the Richards's medium. There was no growth at pH 1·5, 2·0, 2·8 and 8·6 ; poor growth at pH 4·5 and 5·3 and good growth of the fungus at pH 6·1, 7·0 and 7·8. The optimum growth of 1·682 gm. was obtained at pH 7·0 Thus the fungus grew fairly well between pH values 4·5 and 7·8 (Table 1).

TABLE 1

Effect of pH on the growth of *Fusarium oxysporum* f. *psidii* in Richard's medium

Initial pH of the medium	Dry weight of the mycelium
1·5	No growth
2·0	,,
2·8	,,
4·5	1·517 gm.
5·3	1·617 gm.
6·1	1·667 gm.
7·0	1·682 gm.
7·8	1·635 gm.
8·6	No growth

It is evident from the data given in table 2 that the application of sulphur to the soil lowered the pH reaction from 8·0 to 4·2 at Allahabad and from 7·7 to 4·4 at Lucknow, but did not lower the severity of wilt appreciably. Molasses were less effective in lowering the pH of the soil and were more or less ineffective in preventing the wilt disease both at Allahabad and Lucknow. But the mortality of guava trees due to wilt was appreciably lowered by the application 4 lbs. lime

to the soil at the base of the wilting tree as compared to the untreated controls, both at Allahabad and Lucknow. The application of gypsum to the soil at the same rate also lowered the wilt incidence but not to same extent (Table 3).

TABLE 2

Effect of Soil treatment with sulphur, molasses and lime on the severity of guava wilt at Allahabad and Lucknow, 1953–61

	Allahabad			Lucknow		
Treatment	pH of the soil before treatment	pH of the soil after treatment	Wilt percentage after treatment	pH of the soil before treatment	pH of the soil after treatment	Wilt percentage after treatment
Sulphur	8·0	4·2	25·0	7·7	4·4	12·5
Molasses	8·0	7·1	28·6	7·8	7·1	12·5
Lime	7·9	8·4	10·7	7·6	8·1	0·0
Control	8·0	7·8	27·8	7·6	7·8	14·2

TABLE 3

Effect of Soil treatment with lime and gypsum on the severity of guava wilt at Allahabad, 1957–61

	Minto Park			Sallahpur			Pryag Vidyapeeth		
Treatment	pH of the soil before treatment	pH of the soil after treatment	Wilt percentage after treatment	pH of the soil before treatment	pH of the soil after treatment	Wilt percentage after treatment	pH of the soil before treatment	pH of the soil after treatment	Wilt Percentage after treatment
Lime	7·4	8·3	8·0	7·1	7·5	3·0	7·2	7·7	7·0
Gypsum	7·5	7·4	14·0	7·1	7·0	5·5	7·2	7·0	10·0
Control	7·1	7·2	20·0	7·1	7·2	11·0	7·2	7·2	17·0

Discussion :

Mehta's hypothesis (1951) that alkaline soils favour the development of guava wilt was not substantiated by further work reported in this paper. The fungus does not grow at pH lower than 4·5 and higher than 8·6 Thus, acidity or alkalinity of the soil seems to play little part in the development of this pathogen. It is possible that by lime treatment, an additional quantity of calcium may be supplied to the soil and thereby the toxins produced by the guava wilt organism are neutralized. McNew (1953) considered the possibiiity of calcium influencing plant diseases indirectly by neutralising the toxins produced by wilt-inducing fungi and thus bringing about a change in the physiological balance of the host tissues to the detrement of the parasite. However, the exact role of lime in reducing the incidence of guava wilt is not well understood and needs further investigation.

Summary :

The growth of *Fusarium oxysporum* f. *psidii* is not favoured by acidic or highly alkaline Richards's medium. The fungus grows within a pH range of 4·5 to 7·8 with optimum growth at pH 7·0

The application of sulphur and molasses six inches below soil level in the root zone of the wilting guava trees is ineffective in controlling the disease.

The application of lime or gypsum at the rate of 4 lbs. per tree reduced wilting, application of lime being superior, although the role played by these chemicals in controlling the disease is not well understood.

Acknowledgements :

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References :

Anderson, P. J. and Morgan, M. F. *Conn. Agr. Exp. Sta. Tobacco Sta. Bull.*, **6** : 59 T–66 T., 1926.

Bennet, F. T. *Ann. Appl. Biol.*, **26** : 837–841, 1939.

Duff, G. H. and Welch, C. G. *Phytopathology*, **17** : 297–314, 1927.

Garrett, S. D. Root disease Fungi. Chronica Botanica Co. Waltham, Mass. U. S. A., 1944.

Martin, W. H. *Soil Sci.*, **16** : 69–73, 1923.

Mehta, P. R. *Pl. Prot. Bull.*, **3** : 7–12, 1951.

Taubenhaus, J. J. and Ezekiel, W. N. *Texas Agr. Exp. Sta. Bull*, 423, 1947.

INTER-RELATIONSHIP BETWEEN STANDARD LENGTH AND BODY-WEIGHT OF *CIRRHINA MRIGALA* (HAMILTON)

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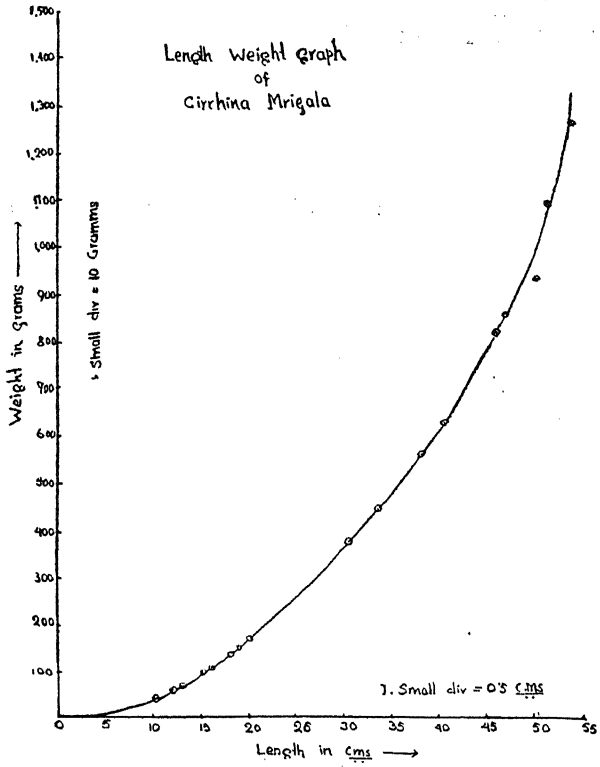
The inter-relationship between length and weight of a fish has often been studied biologically. In solving taxonomic problems (Speirs, 1952) it is very useful to be able to determine the weight of a fish when length alone is known (or vice versa). Results of such studies do have a practical value as in regulating fisheries.



Graph I

The present paper deals with the inter-relationship between standard length and body-weight of *Cirrhina mrigala* (Hamilton) on the basis of the LeCren formula (1951). The fishes for the study were collected from the Ranchi Lake during the year 1960–61.

Since we know that—

$$W = aL^n \qquad \text{(LeCren, 1951)}$$

where : W = Weight, L = Standard Length, '*a*' is a canstant and '*n*', an expenent

therefore $\log W = \log a + n \log L$.

If a graph of log L and log W is plotted with log L along the X axis and log W along the Y axis, the graph will be a straight line, the tangent of the slope of which will give the value of '*n*' and the intercept on the Y axis for log L = O will give the value of log *a*.

In the actual graph drawn (Graph II), the origin was not log L = O, hence for calculating log *a*, instead of drawing a large graph which was of no use, certain geometrical properties were utilized.

When log L is equal to 1·7 (*vide* Graph II),

$$\log W = 3{\cdot}012,$$

and for, $\log L = 0{\cdot}86,$

$$\log W = 1{\cdot}3$$

Therefore $$n = \frac{3{\cdot}012 - 1{\cdot}3}{1{\cdot}70 - 0{\cdot}86} = 2{\cdot}0357$$

i.e. $n = 2{\cdot}0357.$

From the equation

$$\log W = \log a + n \log L, \text{ which is the same as}$$
$$Y = mx + c$$

On a comparison of these two equations, it is evident that *n* plays the role of *m* and log *a* of *c*.

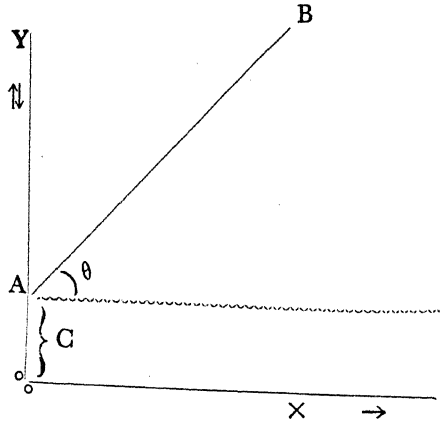


Fig. I

The straight line AB of Fig. I is the line which satisfies the equation :

$$Y = mx + c \text{ and}$$
$$m = \tan \theta$$

TABLE I

Showing the standard length, actual weight, calculated weight and percentage variations of *Cirrhina mrigala* (Hamilton)

Serial No. of observation	Length in Cm.	Log. L	Actual in Grams	Log. W	Calculated Log. W	Weight calculated in Grams	Percentage variation
1	10	10000	30	1·47712	1·58294	38·27	+27·56
2	12	1·07918	50	1·69897	1·7437603	55·43	+10·86
3	13	1·11394	60	1·77815	1·8129741	65·01	+8·35
4	14	1·14613	70	1·84510	1·8801522	75·86	+8·37
5	15	1·17609	85	1·92942	1·9412232	87·33	+2·73
6	16	1·20412	100	2·0000	1·9982228	99·59	—0·49
7	18	1·25527	132	2·12057	2·1020435	126·47	—4·2
8	19	1·28775	143	2·15534	2·1488646	140·86	—1·5
9	20	1·30103	165	2·21748	2·1956857	156·93	—4·9
10	23	1·36173	220	2·34242	2·3178277	207·87	—5·51
11	30	1·47712	370	2·56820	2·5539689	358·10	—3·22
12	34	1·53148	450	2·65321	2·6638967	461·12	+2·48
13	38	1·57978	568	2·75435	2·7616103	577·57	+1·69
14	40	1·60206	635	2·80277	2·8084314	643·28	+1·30
15	42	1·62325	708	2·85003	2·8511811	711·20	+0·45
16	44	1·64345	765	2·88366	2·8918951	779·20	+1·92
17	45	1·65321	820	2·91381	2·9122521	817·17	—0·34
18	46	1·66276	862	2·93551	2·9305734	852·31	—1·13
19	48	1·68124	939	2·97267	2·9692517	931·53	—0·79
20	50	1·69897	1100	3·04139	3·0038586	1009·00	—8·3

Keeping this fact in view, '*n*' has been calculated from the graph (No. II) '*c*' in (Fig. I) is the intercept of the line AB on the Y axis when X=O. Hence, it is necessary that the graph (No. II) must have its origin log L=O. But we know that when log L decreases from 1·7 to 0·86, *i.e.*, by 0·84, log W decreases from 3·102 to 1·3 *i.e.*=1·712. Therefore when log L will decrease from 0·86 to O, log W will decrease by

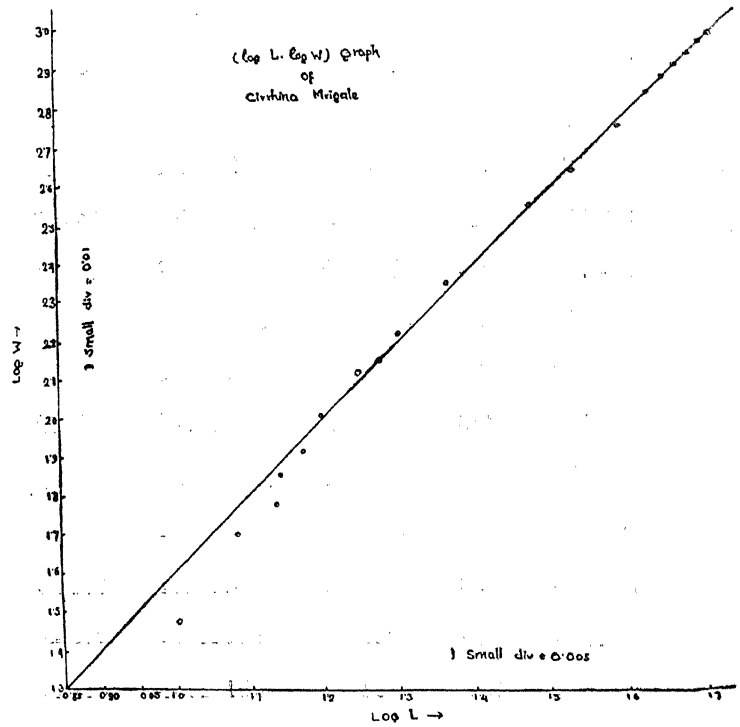
$$\frac{1{\cdot}712\times 0{\cdot}86}{0{\cdot}84} = 1{\cdot}75276.$$

Hence the intercept on Y axis for log L = O, will be

$$1{\cdot}3 - 1{\cdot}75276 = -0{\cdot}45276$$

Therefore log $a = -0{\cdot}45276$

and $a = 0{\cdot}35256$

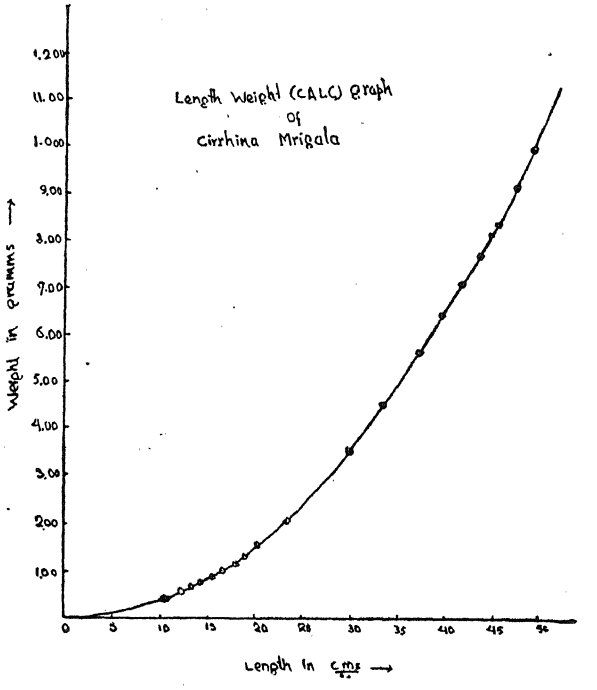


Graph II

Now after obtaining the values for '*a*' and '*n*' the weight of each individual was calculated and a graph with length along X axis and calculated weight along Y axis was drawn (Graph III).

A comparison of the actual weight with the calculated weight of *Cirrhina mrigala* shows that for smaller fishes, there is a veay apparent difference between the two, whereas for the fishes with higher lengths the actual and calculated weights are almost equal and their variations are negligible. Normally the value

of '*n*' ranges from 2·5 to 4 as has been indicated by Margaret E. Brown (1957). But in our study the value comes to 2·0357.



Graph III

From table 1 it is apparent that the calculated weights show variations in the fishes which are appreciably significant for lower length, whereas for larger length, the calculated weights tally with the actual weight taken. It is, therefore, concluded that the formula as adopted by LeCren *i.e.*

$W = a\ L^n$ is applicable more uniformly in the case of fishes with larger length.

References :

Beckman, Williams C. The length-weight relationship, factors for conversions between standard and total lengths and Co-efficient of condition for seven Michigan fishes. *Trans. Amer. Fish. Soc.* **75** : 237–256, 1948.

Brown, E. Margaret. The Physiology of Fishes, **I** : 370–372.

Lagler Karl, F. Fresh water Fishery Biology, 159–165, 1956.

LeCren, E. D. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). *Jour. Animal Ecology*, **20** (**2**) : 201–219, 1951.

THE CRANIAL NERVES OF *WALLAGO ATTU* (BL. & SCHN.)

By

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Introduction :

Although the bony fish is being dissected for its cranial nerves in the B.Sc. and M.Sc. classes in all the Indian Universities, no good account of them is available. The present contribution provides a reasonably complete account of the cranial nerves of the catfish, which is abundantly available in all parts of India and is represented by a single species in the country.

The Cranial Nerves :

There are the usual ten pairs of nerves, which are symmetrically disposed on the two sides of head.

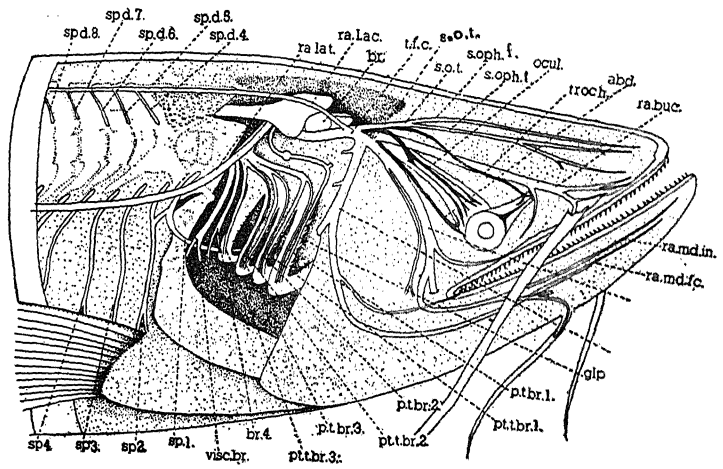

Fig. 1

Side view of the Cranial Nerves

abd., abducent nerve ; *br.*, brain ; *br. 4.*, fourth branchialis of vagus nerve ; *glp.*, glossopharyngeal nerve ; *h.m.t.* hyomandi. bular trunk ; *i.o.t.*, infra orbital trunk ; *p.t.br. 1–3.*, pretrematic branch of first, second and third branchialis of vagus nerve ; *ocul.*, oculomotor nerve ; *pt.t.br. 1–3.*, posttrematic branch of first, second and third branchiales of vagus nerve ; *ra.lat.*, ramus lateralis of vagus nerve ; *ra.buc.*, ramus buccalis ; *ra.l.ac.*, ramus lateralis accessorius ; *ra.md.fc.*, ramus mandibularis facialis ; *ra.md.in.*, ramus mandibularis internus ; *ra.md.tr.*, ramus mandibularis trigeminalis ; *s.op.f.*, ophthalmicus superficialis facialis nerve ; *s.oph.tr.*, ophthalmicus superficialis trigeminalis nerve ; *s.o.t.*, supraorbital trunk; *sp. 1–4* ; ventral branches of first to fourth spinal nerves ; *sp.d. 8–4.*, dorsal branches of fourth to eighth spinal nerves ; *tr.f.c.*, trigeminofacial complex ; *visc.br.*, visceralis branch of vagus nerve.

The *olfactory nerve* (Figs. 2 and 3 ; olf.) arises from the front end of olfactory lobe and immediately divides into two strands, which run forward on the ventral side of olfactory rosette. The strands are small and give branches to the olfactory folds in the anterior half of rosette. The folds in the posterior half of rosette are supplied by fine strands, which arise directly from the olfactory lobe.

The *optic nerve* (Fig. 2 ; opt.) comes out from the optic thalamus of diencephalon. The two nerves emerge on the ventral side of brain and cross to the opposite sides beneath the cerebrum. Each nerves then passes out into the orbit through the optic foramen situated between the pleurosphenoid and parasphenoid. Surrounded by the optic pedicel it runs above the maxillaris and buccalis rami and enters the eye ball to supply its retina.

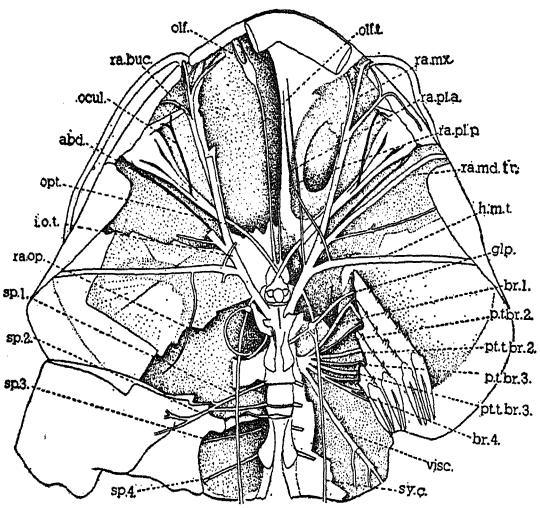

Fig. 2

Ventral view of the Cranial Nerves

abd., abducent nerve ; *br.l.*, first branchialis of vagus nerve ; *br. 4.*, fourth branchialis of vagus nerve ; *glp.*, glossopharyngeal nerve ; *h.m.t.*, hyomandibular trunk ; *i.o.t.*, infraorbital trunk ; *ocul.*, oculomotor nerve ; *olf.*, olfactory nerve ; *olf.t.*, olfactory tract ; *opt.*, opt., optic nerve ; *p.t.br. 2 & 3.*, pretrematic branches of second and third branchiales of vagus nerve ; *pt.br 2 & 3.*, post-trematic branches of second and third branchiales of vagus nerve ; *ra.mx.*, ramus maxillaris ; *ra.buc.*, ramus buccalis ; *ra.op.*, ramus operculars ; *ra.md.tr.*, ramus mandibularis trigeminalis *ra.pl.a.*, ramus palatinu santerior ; *ra.pl.p.*, ramus palatinus posterior ; *p. 1-4.*, first to fourth spinal nerves ; *sy.c.*, sympathetic cord., *visc.*, visceralis branch of vagus nerve.

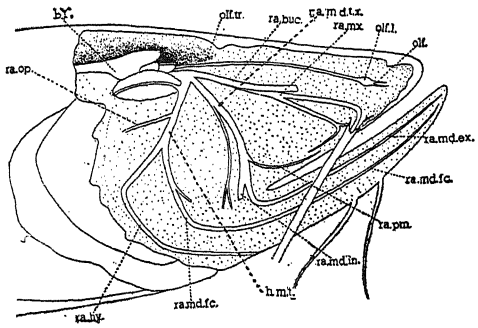

Fig. 3.

Side view of the Cranial Nerves

br., brain ; *h.m.t.*, hyomandibular trunk ; *olf.tr.*, olfactory tract ; *olf. l.*, olfactory lobe ; *olf.*, olfactory nerve ; *ra.buc.*, ramus buccalis ; *ra.hy.*, ramus hyoidean ; *ra.mx.*, ramus maxillaris ; *ra.md.ex.*, ramus mandibularis externus ; *ra.md.fc.*, ramus mandibularis facialis ; *ra.md.in.*, ramus mandibularis internus ; *ra.md.tr.*, ramus mandibularis trigeminalis ; *ra.pm.*, ramus premaxillaris ; *ra.op.*, ramus opercularis.

The *oculomotor nerve* (Figs. 1, 2 and 4 ; ocul.) is slender and arises from the ventral side of mid brain, concealed below the hind end of inferior lobe. It enters the orbit through the optic foramen slightly in front of the optic nerve and passes below the ophthalmicus superficialis trigeminalis and ophthalmicus superficialis facialis rami and divides into two branches, a superior and an inferior.

The superior branch supplies the superior rectus muscle, while the inferior branch passes down between the superior rectus and posterior rectus muscles to the ventral side of eye muscles. Here it separates into two branchlets, one passes to the inferior oblique muscle and the other running above the inferior rectus and giving a twig to it terminates in the anterior rectus muscle.

The *trochlear nerve* (Figs. 1 and 4 ; troch.) is given out from the dorso-lateral aspect of brain between the optic lobe and cerebellum, concealed below the hind end of optic lobe. It accompanies the supraorbital trunk of trigeminofacial complex for some distance and comes out into the orbit through a foramen in the orbitosphenoid. It passes dorsal to the optic and oculomotor nerves and ends in the superior oblique muscle.

The *abducent nerve* (Figs. 1, 2 and 4 ; abd.) arises from the ventral aspect of medulla oblongata behind the origin of trigeminal nerve. It runs outwards and enters the orbit through the foramen for the infraorbital trunk of trigeminofacial complex and passing below the oculomotor nerve innervates the posterior rectus muscle.

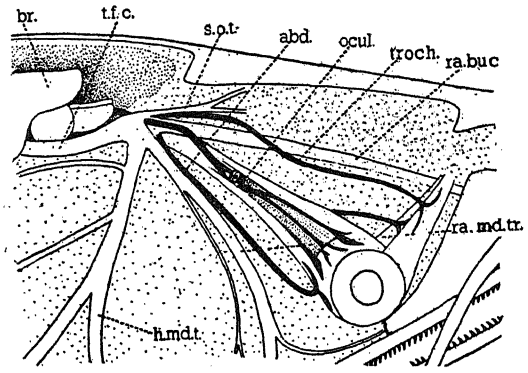

Fig. 4

Eye Muscle Nerves

abd., abducent nerve ; *br.*, brain ; *h.md.tr.*, hyomandibular trunk ; *ocul.*, oculomotor nerve ; *ra.buc.*, ramus buccalis ; *ra.md.tr.*, ramus mandibularis trigeminalis ; *s.o.t.*, supraobital trunk ; *t.f.c.*, trigeminofacial complex ; *troh.*, trochlear nerve.

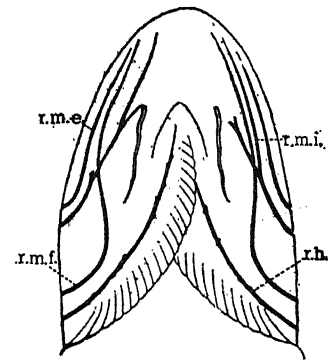

Fig. 5

Ventral view of Cranial Nerves

r.a.e., ramus mandibularis externus ; *r.mi.*, ramus mandibularis internus ; *r.m.f.*, ramus mandibularis facialis ; *r.h.*, ramus hyoidean

The *trigeminal* and *facial nerves* (Figs. 1–5 ; t.f.c.) arise from the side of medulla one after another. Although quite independent at their origin, the two join immediately to form the trigeminofacial complex, which separates into three trunks, the supraorbital, infraorbital and hyomandibular.

The *supra orbital trunk* (Fig. 1; s.o.t.) arises as a stalk from the trigeminofacial complex dorsal and internal to the infraorbital trunk. It runs forward and comes into the orbit through the foramen in orbitosphenoid along with the trochlear nerve. Inside the orbit the trunk separates into two rami, the inner *ophthalmicus superficialis facialis* and the outer *ophthalmicus superficialis trigeminalis*, which run forward almost parallel to one another. They pierce through the lateral ethmoid and rise up in the skin on inner side of the olfactory capsule. The ramus ophthalmicus superficialis trigeminalis gives off a branch from its outer side, which

pushes forward to supply the skin of snout on the outer side of olfactory capsule. The ramus ophthalmicus superficialis facialis innervates the supraorbital canal of lateral-line system.

The *infraorbital trunk* (Fig. 2 ; i.o.t.) passes out through the foramen bounded by the pleurosphenoid, prootic and parasphenoid. In the orbit it runs forward and outward to the level of front end of the cerebrum and separates into three rami, the maxillaris, buccalis and mandibularis trigeminalis. The *ramus maxillaris* (Figs. 2 and 3 ; ra.mx.) runs forward and outward in the direction of maxillary barbel. It lies intimately associated with the ramus buccalis in its earlier course and at about the middle of the run the two are connected by a branch. A little beyond this connection it separates into two branches, the inner passes to the maxillary barbel and the outer divides to supply the upper lip and premaxillary teeth.

The *ramus buccalis* (Figs. 1–3 ; ra.buc.) follows a course similar and dorsal to that of the ramus maxillaris. Inside the orbit a branch from it curves back to the region in front of eye. About the level of hind end of the olfactory sac it bifurcates into an inner and an outer branch. The inner branch runs to the anterior end of snout on the outer side of olfactory capsule, while the outer branch separates into two branchlets. The inner slender branchlet terminates on the skin of snout and the outer more prominent branchlet passes to maxillary barbel to supply the sense organs on it.

The *ramus mandibularis trigeminalis* runs along the posterior border of eye and on reaching the angle of mouth divides into the ramus mandibularis externus and ramus mandibularis internus. The *ramus mandibularis externus* (Figs. 3 and 5 ; ra.md.ex.) passes to the lower jaw on outer side of the angular and dentary and runs in a superficial course to the anterior end of mandible. All along its course it gives twigs to the overlying skin. The *ramus mandibularis internus* (Figs. 1 and 5 ; ra.md.in.) also decends into the mandible, but follows a course deeper to that of the externus branch. It enters the inner side of angular and after giving a nerve to the inner side of dentary, it turns in and forks into two branchlets. The inner branchlet supplies the mandibular barbel, while the outer branchlet runs forward to the anterior end of head.

Before its separation into the maxillaris, buccalis and mandibularis rami, the infraorbital trunk gives off from the ventral aspect the slender *ramus palatinus anterior* (Fig. 2 ; ra.pl.a.), which runs forward on the roof of buccal cavity internal to the ramus maxillaris and ramus buccalis.

The *hyomandibular trunk* (Figs. 2 and 4 ; h.m.t.) passes out through a foramen in the hyomandibula, after its separation from the trigeminofacial complex. The trunk runs over the hyomandibula and divides into the ramus mandibularis facialis and ramus hyoideus. Immediately on escaping from the cranium, the hyomandibular trunk gives off a slender branch, which extends back and supplies the hind end of operculum. Before its separation into these two branches, it gives off the stout *ramus opercularis* (Figs. 2 and 3 ; ra.op.), which directed downwards and backwards innervates the operculum. The *ramus mandibularis facialis* (Figs. 1 and 3; ra.md.fc.) passes over the hyomandibula and quadrate and a little before the cleft of mouth gives off a slender cutaneous branch, which supplies the lower lip and mandibular teeth. After giving this branch the main nerve descends down and entering the mandible runs to its anterior end in the groove on inner side of the angular and dentary.

The *ramus hyoideus* (Fig. 3 ; ra.hy.) descends over the hyomandibula and enters the groove between it and preoperculum. In the groove it follows downwards and passes to the branchiostegal membrane on the underside of head. The ramus hyoideus and ramus mandibularis facialis innervate the operculomandibular canal of lateral-line system.

Beyond the origin of ramus opercularis, hyomandibular trunk gives off the slender *ramus palatinus posterior* (Fig. 2 ; ra.pl.p.), which runs forwards and inwards crossing the other nerves and pushes forward on inner side of the ramus palatinus anterior to supply the roof of buccal cavity.

From each *trigeminofacial complex* arises the *lateralis accesorius* strand (Fig. 1 ; ra.l.ac.), which rises up in the angle between the cerebellum and acoustic tubercle of its side and emerges out of the cranium by a foramen in the supraoccipital. The two accessorius strands run backwards on either side of the occipital crest and neural spines of the vertebrae serving as receivers of the dorsal rami of spinal nerves.

The *auditory nerve* comes out from the lateral side of medulla, close behind the origin of facialis nerve. It divides immediately into two branches, the vestibular and saccular. The *vestibular branch* passes directly outward and by a number of branchlets supplies the utriculus and ampullae of the semicircular canals. The *saccular branch* runs back underneath the medulla and anterior part of the spinal cord and at the level of sacculus separates into a number of twigs, which supply the sacculus, lagena and sinus endolymphaticus.

The *glossopharyngeal nerve* (Figs. 1 and 2 ; glp.) arises by two roots from the ventro-lateral side of medulla behind the origin of auditory nerve. The two roots unite and the combined trunk runs backward and passes out of the cranium through the foramen on the ventral face of exoccipital. On emergence it swells up into a ganglion and beyond it runs forwards and then downwards reaching the first branchial arch. As it enters the arch to supply the first gill, it gives a branch to the roof of pharynx.

The *vagus nerve* (Figs. 1 and 2) has a much more extensive distribution than the other cranial nerves. It arises by two roots from the ventro-lateral aspect of medulla immediately behind the origin of glossopharyngeal. The two roots unite and the common trunk develops the vagus ganglion, before the trunk issues out of the cranium through its foramen at the hind end of exoccipital. The *lateralis* trunk of vagus separates first from the nerve and then the *branchio-visceralis* trunk issues out separately from cranium. On emergence the branchio-visceral trunk separate into five branches, the first four branchiales and the fifth visceralis. Each *branchialis branch* (Figs. 1 and 2 ; br. 1-4) gives off dorsally a fine pharyngeal branch to the pharynx and then in a course similar to that of the glossopharyngeal nerve runs to the first gill cleft, where it divides into two branches, one behind the other. The slender anterior pretrematic branch runs forward in a superficial course to the gill along the anterior border of cleft. The stout posterior post-trematic branch gives off a fine strand to the mucous membrane of cleft and is distributed in a deeper course to the succeeding gill along posterior border of the same cleft. The first branchialis branch in this manner supplies the first and second gill ; the second branchialis the second and third gill ; the third branchialis the third and fourth gill ; and the fourth branchialis the fourth gill and the mucous membrane of the part of branchial cavity behind the fourth gill.

The *visceralis branch* (Figs. 1 and 2 ; visc.br.), divides into two branches after a short run along the posterior border of gill cavity. The anterior branch runs forward on the floor of branchial cavity and supplies the pericardium and heart. The posterior branch runs back and entering the body cavity supplies the viscera.

From the vagus nerve close to its origin from the medulla arises the stout *lateralis trunk* (Fig. 1 ; ra.lat.). It runs downwards and outwards till it reaches the lateral-line canal over the base of pectoral fin. It then proceeds back up to the posterior end of tail, running along and beneath the lateral-line canal, which it innervates by numerous branches.

Summary :

1. The olfactory nerve supplies the front half of rosette by its two branches. The posterior half of rosette is innervated by fine branches from the olfactory lobe.

2. The eye muscle nerves are very thin owing to the eyes being reduced. The superior branch of oculomotor nerve supplies the superior rectus muscle, while the inferior branch innervates the anterior rectus, inferior rectus and inferior oblique muscles.

3. The trigeminal and facial nerves join intracranially into the trigemino-facial complex. The supraorbital trunk is well formed and the ramus ophthalmicus superficialis facialis innervates the supraorbital canal of lateral-line system.

4. The infraorbital trunk is small and gives the ramus palatinus anterior to the palate. The ramus maxillaris innervates the maxillary barbel and the ramus buccalis supplies the sense organs on this barbel. The externus and internus branches of the mandibularis trigeminalis enter the lower jaw.

5. The hyomandibular trunk gives off the ramus opercularis to the operculum and ramus palatinus posterior to the palate. Its mandibularis facialis branch innervates the mandibular canal of lateral-line system. The ramus lateralis accesorius receives the dorsal rami of spinal nerves.

6. The vestibular branch of auditory nerve supplies the utriculus and ampullae of the semicirbular canal, while the saccular branch is distributed to the sacculus, lagena and sinus endolymphaticus.

7. The ganglion of glossopharyngeal nerve is extra-cranial. It innervates the first gill. The ganglion of vagus nerve is intra cranial. The fourth branchialis branch supplies the fourth gill and hind wall of branchial cavity. The anterior branch of visceralis innervates the heart, while the posterior branch supplies the viscera. The lateralis arises separately from the vagus and supplies the lateral-line canal.

References :

Allis, E. P. The skull and the cranial and first spinal muscles and nerves in *Scomber scomber*. *J. Morph. Philadelphia* **XVIII** : 45–328, 1903.

Ariens-kappers, C. U., Huber, G. C. and Crosby, E. C. The comparative anatomy of the nervous system of vertebrates. 2 Volumes. pp. 1–1845, 1936.

Atoda, K. The innervation of the cranial nerves of catfish, *Parasilurus asotus*. *Sci. Rep. Tohoku Univ.* **XI** : 91–115, 1936.

Berkelbach, H. and Sprenel, V. P. The cranial relations of the cranial nerves in *Silurus glanis* and *Mormyrus cuochive*. *J. Comp. Neur. Philadelphia*, **XXV** : 5–63, 1915.

Brookover. C. and Jackson, E. S. The olfactory nerve and the nerve terminalis of *Ameiurus*. *J. Comp. Neur. Philadelphia*, **XXI**: 237–259, 1911.

Herrick, C. J. and Herrick, C. L. Contributions to the morphology of the brain of bony fishes. *J. Comp. Neur. Philadelphia*, **I** : 211–245, 1891.

Herrick, C. J. The peripheral nervous system of the bony fishes. *Bull. U. S. Comm. Fish & Fisheries*, **XVIII** : 315–320, 1898.

——— Cranial nerves and cutaneous sense organs of North American siluroid fishes. *J. Comp. Neur. Philadelphia*, **XI** : 177–249, 1901.

Ray, D. L. The peripheral nervous system of *Lampanyctus leucopsarus*. *J. Morph. Philadelphia*, **LXXXVII** : 61–178, 1950.

Wright, R. On the nervous system and sense organs of *Ameiurus*. *Proc. Canad. Inst. Sci. Toronto*, N. S., **II** : 352–381, 1885.

INDO-TIBETAN CRADLE-LAND OF HUMANITY

By

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On the basis of the palaeontological, climatological and anthropological evidences available so far, the writer holds that the Indo-Tibetan region—in the south and north of the Himalayan belt—has been the original cradle-land of Human Evolution.

The highest order of anthropoid apes evolved into the ancestor of man in the cis-Siwalik Zone of India, from where migration of ape-men took place under the force of changing climates. The primary cradle was the cis-Siwalik Zone, where the climate, flora and fauna were most suitable for human evolution ; afterwards, the cradle extended upto Tibeto-Oxus region, and further evolution of human stock went on, both in the south and north of the Himalayan belt.

The branch of the earliest ape-man bifurcated from the stem of anthropoids (Sivapithecus-Dryopithecus) in Mid-Miocene epoch (last phase of the Lower Siwalik deposits) in the Sub-Himalayan Siwalik Zone. It evolved further into Ramapithecus in Early Pliocene (Middle Siwalik) epoch. Ramapithecus evolved into Australopithecus, and further into Meganthropus and Pithecanthropus in Late Pliocene. Under the force of changing climate, and shift of the tropical belt to the south, these anthropoids migrated southwards. Australopithecus migrated to Africa. Pithecanthropus migrated in two-branches : one branch of it migrated to South India and South Asia (Sundaland, which was the ancestor landmass of Java) ; and another branch crossed over to Tibeto-Oxus Zone. Meganthropus also followed the two-branch route of Pithecanthropus, one towards Java and another towards Tibet. The southern branch of Pithecanthropus appeared as the earliest ancestor of man in Java near the end of the Pliocene epoch. The northern branch of ape-men migrated to East China, where it appeared as Sinanthropus in the beginning of the Pleistocene.

Evidences supporting the theory of Indo-Tibetan Cradle-land :

The following evidences support the writer's view that Indo-Tibetan Zone was the cradle-land of humanity and further variant racial stocks :

(1) Palaeontological finds of Sivapithecus, Dryopithecus, and Ramapithecus from the Siwalik Zone of India.

(2) Climatic evidences of the Tropical phase of the Siwalik Zone, its suitability for human evolution, and shift of the tropical belt to the south, on the initiation of the cold phase.

(3) Common ancestry of Pithecanthropus and Sinanthropus ; Rubicon crossed, and the emergence of ape-man in the cis-Siwalik Zone.

(4) Common origin of the dolichocephalic and brachycephalic races.

(5) South Africa not the cradle of humanity.

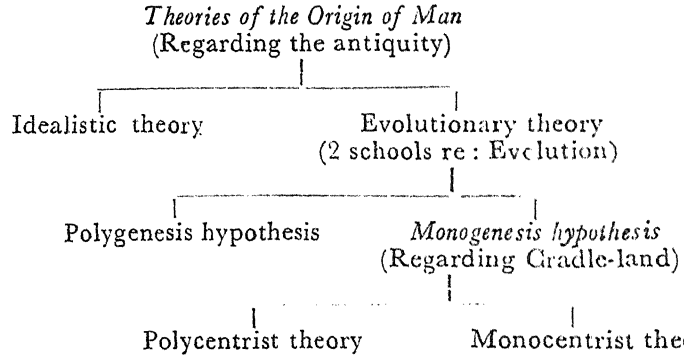
(6) Palaeolithic artifacts of pre-Sohan (pre-Chellean) age and also eoliths found by the writer in outer Himalaya.

(7) Migration of successive racial stocks from the cradle.

The Neo-Monocentrist theory of Human Evolution :

Anthropologists have, from time to time, propounded various theories about the (*i*) antiquity and (*ii*) cradle-land of humanity. The writer has schematised the different hypotheses in the outline given below.

Regarding the antiquity of Man, there are two different lines of thought: (1) Idealistic theory and (2) Evolutionary theory, which itself has two schools—the Polygenesis hypothesis and the Monogensis hypothesis. Regarding the cradle-land too, there are two different theories with several modificatory views—the Polycentrist theory and the Monocentrist theory.



The idealistic hypothesis is based mostly on certain beliefs and philosophical views: it postulates that man has existed on the earth for all times, having absolutely no ancestoral relation with the anthropoid apes. Although its supporters have made use of scientific data to prove the theory, yet it has failed to be adopted by the majority of scientists today. Keith, (1929) who in his early essays supported the Idealistic theory, himself dropped it in favour of a type of Evolutionary theory, which he calls the 'Group Theory'. (Keith, 1947)

Other scientists, like Spengler, Stolyhwo, and Kleinschmidt, (1947) have propounded the view that every species develops as an independent 'biological circle'. It means that man has evolved without any biological ancestoral relations to anthropoids. But, the Idealistic theory has met only a few supporters.

The Evolutionary theory postulates that the human ancestors evolved from anthropoid apes, under environmental influence and through Natural Selection. Its Polygenesis thought assumes that Man's different races have decended from different apes (gibbon, orangutan, gorilla and chimpanzee). The Monogenesis school holds the view that all human races have a common ancestory—the branch of human ancestoral ape bifurcated from the stem of anthropoids and evolved independently into Modern Man.

About the cradle-land, the Polycentrist theory fixes separate areas of the origin and evolution of the different human races, from the very beginning of the anthropogenesis—of course from the same species of ancestoral ape, who had migrated to different areas before the racial evolution began. Keith, Smith, (1931); Weidenreich, (1941) and Gates (1944) support this theory. The Monocentrist theory assumes only one original cradle for the evolution of different

human races, which evolved under the stimulus of changing physical environment, particularly the climate.

The writer holds his Neo-Monocentrist theory, and proposes a necessary amendment in the views of Osborn, Taylor, Mitra and Grabau; the writer supports their views with one difference of opinion regarding the exact location of the cradle-land. Osborn (1915) assumed that the cradle of Humanity was Tibet and Mongolia. Taylor (1949) fixed the cradle-land in Central Asia, near the Caspian-Aral region. Mitra (1927) assumed one centre of Negroid-Australoid stocks in India. Grabau assumed only Tibet to be the cradle. The present writer holds that the original cradle of Human Ancestor was the cis-Siwalik Zone (the present 'Terai' region) of India, where the anthropoids evolved into ape-men, and afterwards the cradle extended over to Tibeto-Oxus Zone.

Emergence of the earliest Ape-man in the cis-Siwalik Zone :

The ancestral man evolved from a highly advanced anthropoid ape in the tropical climato-vegetative zone. The cis-Himalayan belt of Siwalik Stage deposits (Wadia, 1953) contains a preponderance of palaeontological mammalian fauna which consists of the remains of primates belonging to the most highly developed order. In the Siwalik Deposit period, the climate of the cis-Himalayan region was tropical and much warmer than the present one. The findings of Falconer, (1848 Cautley and Lydekker, (1874; 1875–77) and a 'series of brilliant palaeontological researches of Pilgrim, (1910; 1913–15) have unveiled many rich horizons of primates over the whole Siwalik Zone.

During the Late Tertiary Era, a most rapid evolution of mammals of all kinds—herbivorous, carnivorous, rodents, and primates—took place in this highly favourable habitat. The physical environment was most suited to the development of life. The climate was genial; there was a great abundance of food supply by exuberantly rich vegetation, and there were many rivers and lakes for water supply.

There were about 16 genera of anthropoid apes, (Pilgrim, 1913) which showed phylogenetic interrelations. In the Upper Miocene age, the climate (Huntington 1907 ; Brooks 1939 ; Taylor 1919, 1934) of the Siwalik Zone was tropical. Warmth loving primates lived in this tropical zone upto the Mid-Pliocene age. During this period the Siwalik belt was the main habitat of anthropoids, such as Sivapithecus indicus, Dryopithecus, Dryopithecus punjabicus, Indraloris, Bramapithecus, Palaeosimia, Palaeopithecus, Semnopithecus, Ramapithecus, Sugrivapithecus, Cercopithecus, etc. (Pilgrim, 1915).

The Mid-Pliocene epoch was the most important priod in the history of Human Evolution. Between Mid-Pliocene and Late Pliocene, Siwalik primate of the highest order underwent a critical metabolical change, and entered a new stage of Evolution. Sivapithecus evolved into the ancestor of orangutan, (Gregory Hellman and Lewis, 1935, 1939). Dryopithecus punjabicus became the ancestor gorilla. Another group of Dryopithecus evolved into the ancestor of chimpanzee Ramapithecus evolved into Australopithecus and further into Pithecanthropus who was the ancestor of man. Nesturkh (1918) also holds the similar view : "Man derived from one of the South Asian forms of ape that developed from Early Pliocene anthropoid apes of Ramapithecus type." (Nesturkh, 1959)

Siwalik Ramapithecus was the anthropoid ancestor of man. His fossil finds show a closer relation to man. In his upper jaw, there is no diastema between the sockets of the canine and the first premolar, for the lower canine to enter when the jaws are closed. During the Mid-Pliocene, he evolved into Paranthropus and

further into Australopithecus, who migrated to South India and Africa. One branch went over to Tibet. In Late Pliocene was the appearance of Pithecanthropus, who migrated to Sundaland.

In Late Pliocene, the Siwalik anthropoids followed the southward shift of the climato-floral belt. These anthropoids had crossed the Rubicon in the cis-Siwalik Zone. On the initiation of the cold climate in the cradle, the Australopithecus had to exercise his wit to survive. He had seen forest fires being kindled when bamboos and other floral branches had rubbed together under the force of stormy winds; he also knew that fire gave warmth. In order to avoid cold, he experimented by rubbing sticks of wood and was successful in producing fire. Thus, he became Australopithecus promethcus (fire using anthropoid of southern region) before his migration to South India and further to Africa and South East Asia, under the the force of advancing cold belt.

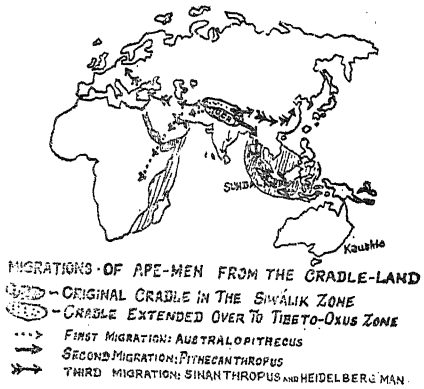


Fig. 3. Sketch Map showing the migrations of anthropoids (ancestral men) from the cradle.

From the cradle, the first wave of migration took place in Late Pliocene, when Australopithecus migrated to Africa. The second wave was that of Pithecanthropus, one branch of which migrated to Sundaland and reached Java at the end of the Pliocene; the second branch of Pithecanthropus crossed over to the Tibetan Zone, and afterwards bifurcated to Oxus and East China, reaching there as Sinanthropus in the beginning of the Pleistocene. All these migrations of Australopithecus, Pithecanthropus and Sinanthropus from the cradle-land to Africa, Java and East China, were of such ancestors of man as used fire and lived on food both vegetarian and non-vegetarian. They hunted animals and used crude stone tools. Skulls of baboon are unearthed from the sites of the skeletal burials of Australopithecus africanus; it shows that the later hunted the former. Although no stone tools were found near the relics of Pithecanthropus in Java, yet it is to be remembered that the few bones of Pithecanthropus were found not *in-situ* but in a drift deposit; and there is every probability of Pithecanthropi using stone tools. Stone implements of Java Man were found by Koeningswald (1937). According to Dubois, (1894) (who discovered the bones of Pithecanthropus, in the Trinil Valley of Java), Pithecanthropi beloged to the very beginning of the Pleistocene.

Common ancestry of Pithecanthropus and Sinanthropus :

Pithecanthropus (Nesturkh, 1959) of the Trinil valley of Java preceded the Sinanthropus (Weidenreich, 1942, 1945) of Choukoutin (37 miles to the south-west of Peking). The Peking breed was "considerably larger brained than the

Trinil breed." (Keith, 1948). The mean capacity of the Peking skulls was 1,070 c.c. (smallest 915 c.c. and largest 1,225 c.c.), while the capacity of the Trinil skull was 935 c.c. Because of this increase of brain, the Peking skulls had higher vaults, and less receding foreheads, yet they retained the supra-orbital torus of anthropoids; teeth and jaws were robust, but a true human chin had made its appearance. "Although the Peking breed had advanced a degree nearer to modern man than the Trinil race, yet, as there are so many points in common between the two, we must infer both had sprung from the same ancestory at no very remote date." (Keith 1948).

Common Origin of the dolicl ocephalic and brachycephalic races :

The common origin of the races is proved by the following findings :

(1) Grimaldi skeletons of man and woman, found in La Grotte des Enfants Menton, France, have Negroid features. (Verneau, 1906)

(2) Cro-Magnon skeletons from Cro-Magnon cave on River Vezere, Dordogne, France, represent a tall race of people with stature 180 cm. (6 ft.). Thye had very great cranial capacity of the skull--one of the five skulls had 1,590 c.c. capacity.

(3) Skeletons from Mursak-Koba grotto, on River Chornaya, in Crimea are of Negroid features. The male skeleton has a length of 180 cm. (Bibikov, and Zhirov 1940).

(4) Skeletons from Fatima-Koba cliff, Russia, indicate Negroid admixture. (Bibikov, Trusova and Gerasimove, 1955).

(5) Kostenki skull XIV, from Upper Palaeolithic burial of Markina Gora, on the banks of the Don, south of Voronezh, has a very wide nasal orifice and the prognathus jaws. It represents typical Negroid features. The mixture of Negroid and Alpine feature resembles that of Grimaldi, and proves the phylogenic relation of the races. (Debets, 1955).

(6) Neanderthal features are found in the Cro-Magnon type skeletons of Brunn, Czechoslovakia (J. Matiegka, 1935).

(7) Skeletons from Oberkassel, near Bonn in Germany, represent Cro-Magnon type with Neanderthal features (heavy supra-orbital arches). (Osborn, H., 1924; Werth, E., 1929).

(8) Podbaba skulls, from Tilbury, east of London, indicate Neanderthal features.

(9) Intermediate types between the earlier races and later races of man are found in U. S. S. R., in the skeletal finds of Podkumok, Skhodnya, Khvalinsk, Severskaya, etc. (Nesturkh, 1959).

South Africa was not the cradle of humanity :

Keith (1948) Dart (1929), and Broom (1946) have assumed that Africa was the cradle of humanity. Keith asserts that the African forerunners of humanity migrated from Africa to Asia and Europe. "The pioneers . . . . turned their faces towards India and ultimately reached Java and North China, where they became the ancestors of the Pithecanthropus and Sinanthropus." (Keith, 1948). Leakey and a few other anthropologists also support the theory of African origin. But their fallacy lies in the non-observation of the finds of the ancestoral anthropoids (Sivapithecus, Dryopithecus and Ramapithecus) in the Siwalik Zone of India.

Those anthropologists, who have tried to avoid India as the original cradle of humanity, have to face the problem of Negrito people, whom they cannot fit in their scheme of racial evolution and migration.

Keith does not recognise the Negrito race as one single race. He writes: "We now turn for a moment . . . pygmy people . . . these dwarfs do not represent a single race, but that they have arisen. . as mutations : that the tendency to produce such mutations is inherent in the germinal constitution of Negroid people." (New Theory, p. 249). Here Keith has reversed the actual process of racial evolution ; as a matter of fact, the Negrito race preceded the Negroid race.

Taylor (1949) has pointed out the inconsistencies in assuming Africa as cradle-land. He writes : "Most anthropologists accept Asia as the cradle-land of the Alpine, Mediterranean, and Australoid races. If we are to assume that the negroes or negritoes evolved in Africa, then we are faced with several inconsistencies. Where did the negroes and negritoes of Melanesia and thereabouts come from? Africa is suggested, the obvious reply is that it is far simpler to assume that both African and Melanesian came from South Asia, *i.e.* the same centre of racial evolution as did the other races . . . . The same arguments apply to the Negritoes, and lead us to accept an Asiatic Cradle-land."

Besides Taylor, Osborn, Mitra, Grabau, Nesturkh, and many other prominent anthropologists hold that the original cradle-land existed in Asia—Central Asia, or Tibet or its neighbourhood. Mitra holds that the cradle of Negroid and Australoid races was in India. Nesturkh holds that there were two divisions of the cradle : one was in the north-east of the Himalayan mountain chain and the other in its south-west (Nesturkh, 1959). Zeuner (1937), assumes that India was the cradle of humanity. Griffith Taylor has assumed two divisions of the cradle-land : one (of Mediterranean Alpine races) in Turkestan, and the other (of Negroid-Australoid races) in southern Asia. He writes : "A Neandertaloid type lived in southern Asia and gave rise to the negroes far back in the Pleistocene—perhaps in the Gunz-Mindel Interglacial . . . next migration . . . of Australoids . . . their cradle-land was father to the east in Asia than was that of the negroes."

Palaeolithic implements found by the writer in Outer Himalayan Zone :

Palaeliths of pre-Sohan (pre-Challean) Age, and the eoliths found by the writer in Outer Himalayan Zone, prove the existence of Early Palaeolithic Man in the Outer Himalayan belt.

The palaeolithic artifacts found by the writer are of two types : one type is 'Coup-de-poing' and the other is lithic spearhead. They were found at the foot of two different eroded terraces, at altitudes between 1550 and 1920 meters, in the Khutnugad Valley, an affluent of the Yamuna, near 30° 41′ 40″ N latitude and 77° 52′ 32″ E longitude, on the eastern side of the Chakrata Ridge, and extension of the Nag Tibba Range, which joins the Nag Tibba with the Bajmara Tibba, between Ramni Reserve Forest and Deoban Reserve Forest, Jaunsar sub-division of Dehra Dun district.

Figure 1 shows a coup-de-poing which is made of medium-grained quartzite rock of dark gray colour. It has a very thin streak of quartz band at a corner. It is 104 mm. long, 48 mm. wide and 35 mm. thick. The top is chipped flat and smoothened. One longitudinal side is chipped both from the top and bottom, with a single slope of 54° from the top and about 50° from the bottom ; this side is convenient for handling. The other side is chipped only from top towards bottom, at a slope of 49°, to make a sharp edge with the bottom margin. This

side has 4. adjacent vertical chippings and it was used for cutting, scraping and bruising. The frontal part is also sharp-edged.

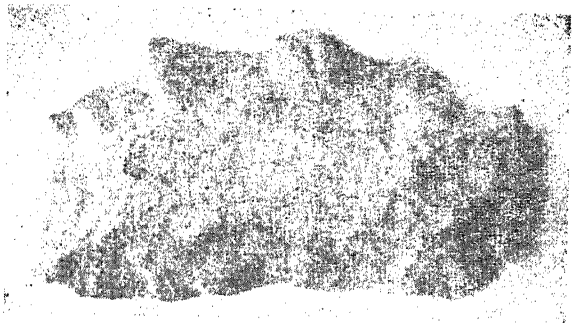


Fig. 1. 'Coup-de-poing', a stone implement, which was used for cutting, scraping and bruising. Palaeolithic man lived by hunting, and he used such a tool for separating flesh from bones and skin (*Photo by Kaushic*).

Figure 2 shows a lithic spearhead, which resembles an arrow-head. It is 118 mm. long, 51 mm. wide and 22 mm. thick. Its frontal triangular part is 72 mm. long and 51 mm. wide. The rear oblong part (its handle-like butt) is 49 mm. on one side and 45 mm. on the other. It is made of medium-grained dark gray quartzite. Other spearheads are also made of quartzite rocks. Some of these artifacts are lithic chisels, and most likely they were used for cutting wood or bone.

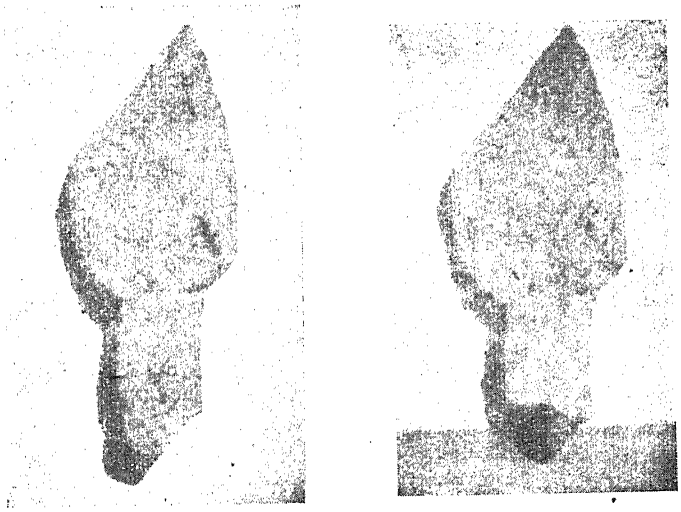


Fig. 2. Lithic spearhead. The spearheads were fitted to wooden staves for hunting animals. (*Photo by Kaushic*).

Ages of these artifacts, and the Palaeolithic Age of India:

The presence of these lithic artifacts proves the abode of Palaeolithic man in the Outer Himalaya and Siwalik Zone. It is quite probable that an excavation

of these terrace.deposits would reveal bones and charred skin of those animals which were hunted by the man of the Stone Age.

Comparisons of these palaeolithic tools with those found by or examined by some prominent scientists in India (Foote, 1915; Logan, 1906 ; Hode Terra and Paterson, 1939), Java (Koeningswald, 1937) China (Black, Wenchung and Weidenreich, 1942) Europe (Hrdlicka, 1927 ; Garrod, 1937 ; Rutot, Moir, 1941 ; Mortilett, Kobler, Edinger, Smith and Yefimenko, 1953), and Africa (Kent, 1943 ; Leakey and Brevil, 1952), arouse further enquiry into the original home of Human Evolution—the cradle-land, from where successive waves of human races migrated to other regions.

The Jaunsar coup-de-poing was found at the foot of a partly eroded terrace belonging to the Early Stage of Gunz-Mindel interglacial period. It belongs to pre-Chellean industry, contemporary to de Terra's pre-Sohan industry. De Terra and Paterson found a good number of stone implements from the boulder conglomerate stage of the Upper Siwaliks.

The writer found the stone spearheads at the foot of an eroded terrace of Mindel Riss interglacial deposit. These spearheads are contemporary to Late Sohan (Mousterian) industry.

Zeuner (1935, 1937, 1945, 1950) has made an excellent study of the Pleistocene epoch. He also supports the view that India was the original home of mankind (Majumdar, 1935). But, he has dated the Palaeolithic period of India from 500,000 years ago to the end of the Pleistocene; while according to the estimate of the present writer, the palaeolithic peried of India dates from about 900,000 or 1,000,000 years ago to the end of the Pleistocene. The Outer Himalayan coup-de-poing belongs to the Early Stage of Gunz-Mindel interglacial deposit, the date of which (600,000 years) is evaluated in the sequel.

Palaeolithic man in India first evolved in the cis-Siwalik Zone of the Upper Indo-Gangetic basin. He existed in the pre-Gunzian period, either at the end of the Pliocene epoch or in the beginning of the Pleistocene epoch. Atleast 300,000 to 400,000 years would have elapsed from the earliest palaeolithic industry to the Jaunsar Gunz-Mindel industry.

The earliest human ancestor, who used stone tools and made palaeoliths in the cis-Siwalik Zone about 1,000,000 or 900,000 years ago, took a considerable time (about 500,000 years) to migrate and reach Western Europe. Zeuner is fully right in giving an antiquity of about 500,000 years to the Heidelberg-man in Gunz-Mindel interglacial. But, Jaunsar palaeoliths beloged to the Earliest Stage of Gunz-Mindel interglacial, atleast 100,000 years earlier than those of the Heidelberg-man.

Holmes (1941 and 1949) has dated the Pleistocene period of glaciation and Stone Age Man from 1,00,000 years ago to 25,000 years ago. He has also given the estimates of minima figures of glacial and interglacial stages of the Alps, alongwith the comparable estimates from America. He writes : "Allowing for the very considerable margin of uncertainty, it can hardly be less than a million years since the first great ice-sheet began its advance—and it may well be more."

von Engeln and Caster (1952) have given the geo-chronology of Man according to which the Gunz stage lasted from 1,000,000 B.C. to 900,000 B.C. (although there is a minor misconception in their scheme regarding the dating of Eonthropus, which is no more believed by the world of scientists today). Kaushic's estimate of the Gunzian period in the Jaunsar Outer Himalayan region is supportad by the above figures.

The National Research Council of U. S. A. has estimated the Pleistocene glacial age to extend over 1,000,000 years upto 11,000 years. (National Research Council, 1937).

Wadia (1953) has suggested a correlation of glacial cycles with the Upper Siwalik stages of North-West India. He has referred to the glaciological investigations of Dainelli, Grinlinton and de Terra in the Kashmir Himalaya, and has given the successive elevations of the sequential glaciation deposits on the wide s nooth glacies of the Pir Panjal Range ;

IV	glaciation	moraine	12,000—9,000 ft. (3658–2743 meters) ;
III	,,	,,	upto 7,000 ft. (2134 meters) ;
II	,,	,,	upto 6,000 ft. (1829 meters) ;
I	,,	,,	upto 5,000 ft. (1585 meters).

The writer found the coup-de-poing near a deposit at about 5,500 ft. (1676 meters) and the lithic spearhead at about 6,300 ft. (1920 meters). The former belongs to the Early stage of Gunz-Mindel interglacial and the latter belongs to the Mindel-Riss interglacial. The ist interglacial dated to about 700,000 years ago.

Nesturkh (1959) has dated the beginning of the Palaeolithic age to 'a period of about 900,000 years.'

Taylor (1949) has given a table of the Pleistocene history to show the evolution of Human Races and Stone Culture in Europe and Asia. He dates Pithecanthropus (Java) to an antiquity of 700,000 years, and shows that the ist glacial phase began about 800,000 years ago. For his dating scheme, he has referred to the works of Sollas (1924), and Osborn (1915). Further, Taylor remarks :

> "It is to be noted that the table is based on data collected in the deposits of Western Europe .... We may assume that man evolved in far distant lands—most of the evidence points to Central Asia—and that many long years elapsed before he reached Western Europe after he had evolved elsewhere."

Keith (1948) also has dated the Pithecanthropus of Java to the Early Pleistocene epoch, although for his counting purposes he has adopted the time scale of Zeuner.

Pithecanthropus used crude tools or eoliths ; and as is shown above, Pithecanthropus had evolved from Ramapithecus in the cis-Himalayan Siwalik Zone and 'Terai' region of of India, during the tropical climatic phase of the Siwalik Zone, before he migrated to Sundaland (Java) consequent upon the migration of the tropical belt of climate, flora and fauna to the south.

Migration of racial stocks from the cradle-land :

There have been successive racial migrations from the cradle-land, under the pressure of climatic changes, which were followed by the changes of flora and fauna.

The preliminary migrations were those of ape-men ; the Paranthropus, Australopithecus, Pithecanthropus and Sinanthropus. Next migration was that of the Heidelberg-man. Further migrations were of human races : Neanderthals and successive races. Racial stocks migrated both from the southern and northern sections of the cradle, in the sequential glaciation periods during the Pleistocene epoch.

Dubois (1894) and von Koeningswald date the Pithecanthropus to the very beginning of the Pleistocene. Nesturkh (1959) is also of the opinion that the Pithe-

canthropi and Sinanthropi lived at the beginning of the Quaternary Period, before the onset of the cold *i.e.* in the pre-glacial times. Heidelberg breed closely followed the date of the Trinil and Peking breeds. Yefimenko assumes that the Heidelberg-man lived somewhat earlier than the Sinanthropus, while Weidenreich (1947), proposes to enlist the Heidelberg-man amongst the Neanderthalers. The present writer's view is that the Heidelberg-man's date was later than that of Sinanthropus and earlier than that of the Neanderthaler, as is given below. The oldest of human fossils of Africa are represented by Rhodesian-man, who migrated in the Gunz glaciation ; he was contemporary to Neanderthal-man.

The first migration was that of Paranthropus from Siwalik Zone, in two branches : one to South India, and the other to Tebeto-Oxus, in Mid-Pliocene. After that, Australopithecus from the Siwalik Zone, in Late Pliocene, to Africa. The third migration was that of the Pithecanthropus from South India to south-east Asia. The south-eastern branch reached Sundaland (Java) at the beginning of the Pleistocene. From the northern branch, in the Tibto-Oxus-Zone, there was a bifurcated migration—one sub-branch migrated towards East China and reached there in Early Pleistocene in pre-glacial period ; the other sub-branch migrated towards the west and reached Western Europe as Heidelberg breed a bit later than the Sinanthropus reached East China, but that too in preglacial period. After that the glacial age commenced ; and during the successive glacial periods variant racial stocks continued migrating both from the southern and northern sections of the Indo-Tibetan cradle-land.

Preliminary migrations

Breed	Migrated from	Migrated to	Period of migration
Paranthropus	Siwalik Zone	Tibeto-Oxus, and S. India	Mid-Pliocene
Australopithecus	Siwalik Zone	South India and then further to Africa and Sundaland	Late Pliocene
Pithecanthropus	South India	To southeast Asia, Sundaland	At the end of Pliocene
		The south-east Asian branch reached Sundaland (Java)	In the beginning of the Pliestocene
Sinanthropus	Northern section of the cradle, *i.e.* from Tibeton Zone	Bifurcated migration : Sinanthropus to East China and	Reached East China in the beginning of the Pleistocene
Heidelberg-man	Northern section, Oxus Zone	Heidelberg-man to Western Europe	Reached Western Europe, in Early Pleistocene, in preice age.

After the initiation of the glacial age, there were 6 glacial epochs in the cradle ; and 4 of them were most effective to force migrations. Therefore, further human breeds had to resort to migration for the sake of existence. In four glacial periods—Gunz, Mindel, Riss and Wurm—there were migrations from both the southern and northern zones of the cradle. During the interglacial periods, there were reversals to the cradle ; but every time only a people turned back and

majority of the migrators settled in the new lands in the outer zones. Every successive racial stock went on pushing forward its predecesor stock towards the periphery of the Asiatic continent, *i.e.* the mainland of the cradle.

Main migrations of the variant racial stocks from the Southern Zone of the cradle, *i.e.* the cis-Siwalik Zone

Racial stock	Evolved in the period	Migrated in the period of
Rhodesian-man	Beginning of the ice-age	Gunz glaciation
Negrito	Gunz-Mindel interglacial	Mindel glaciation
Negroid	Mindel-Riss interglacial	Riss glaciation
Australoid	Riss-Wurm interglacial	Wurm glaciation

Main migrations of the variant racial stocks from the Northern Zone of the cradle, *i.e.* Tibeto-Oxus Sinkiang Zone

Neanderthal	Beginning of the ice age	Gunz glaciation
Mediterranean	Gunz-Mindel interglacial	Mindel glaciation
Early Alpine	Mindel-Riss interglacial	Riss glaciation
Late Alpine (Mongoloid)	Riss-Wurm interglacial	Wurm glaciation

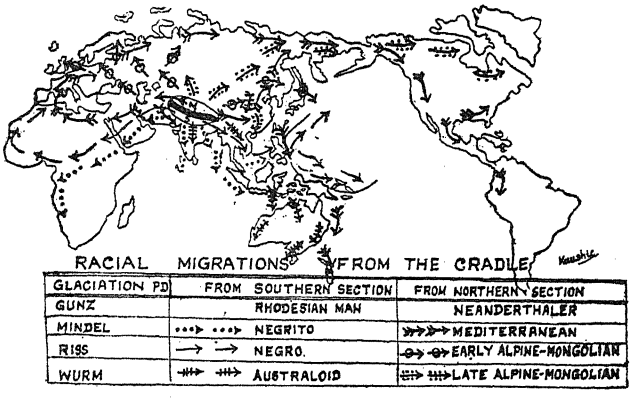


Fig. 4. Map of the racial migration.

Conclusion :

The evidences produced by the present writer, in the foregoing text, with regard to the palaeontological finds of the ancestors of anthropoids in the Siwalik Zone, the Palaeolithic artifacts of pre-Sohan age (of about 700,000 B.C.) in an affluent valley of the Yamuna in Jaunsar, Outer Himalaya, the common ancestry of the Pithecanthropus and Sinanthropus, climatic evidence of the shift of the tropical belt from the cis-Siwalik Zone to the south, common ancestry of the dolichocephalic and branchycephalic races, and the sequence and direction of racial migrations, all prove that the Indo-Tibetan Zone was the cradle-land of humanity.

References :

Bibikov, S. N. and Zhirov, Y. V. Mursak Koba Grotto, *Moscow*, 1940.

Bibicov, S. N., Trusova, S. A. and Gerasimove, M. M. Fatima-Koba skeletons, *Inst. of Antrop.*, Moscow, 1955.

Black, D., Teilhard de Chardin, P., Young, C. and Wen-chung, Pie. Fossil Man in China ; the Choukoutien Cave Deposits, *Geol. Men., Ser. A*, No. LI.

Brooks, C. E. P. The Evalution of Climate, London, 1939.

Brivil, L'Abbe. Stone Tools of Western Morocco, London, *Nature*, **149** : 1942.

Debets, G. F. Kotenski Skull XIV, *Inst. of Antrop.*, Moscow, 1955.

Dubois, E. Pithecanthropus erectus, *Eina Uebergangsform*, Batavia, 1894.

Engeln, von O. D. and Caster, K. E. Geology, New York, 408, 1952.

Falconer, H. D. and Cautley, P. T. Fauna Antique Sivalinsis, London, 1848.

Foote, R. B. Prehistoric and Protohistoric Relics of Southern India, Madras, 1915.

Garrod, Dorothy. The Stone Age of Mt. Carmel, Oxford, I : 1937.

Gates, Ruggles. *Amer. Jour. of Physical Authropology*, N. S., V. 12, 1944.

Gregory, W. K., Hellman, M. and Lewis G. E. Fossil Anthropoids of the Yale, *Cambridge India Expediation*, 1935, *Carnegie Inst.*, Washington, 495, 1939.

Hardlica, A. Neanderthal Phase of Man, *Journal Royal Anthrop. Inst.* London, 1927.

Huntington, E. The Pulse of Asia, Boston, 1907.

Holmes, A. Physical Geology, Edinburgh, 104–5 ; 248, 1944 and 1949.

Kleinschmidt O. : Quoted by M. Nesturkh, Origin of Man, *op. cit.*, p. 7.

Keith, A. A New Theory of Human Evolution, London, 224 ; 225; 226 ; 227 ; 230, 1943.

——— The Antiquity of Man, Vol. I and 2, London, 1929.

——— A New Theory of Human Evolution, London, 1947.

Kent, P. E. The Pleistocence beds of Kanam and Kanjera, *Geol. Mag.* 79 : 1943.

Koeningswald von, G. H. R. Early Man, Edited by G. G. MacCurdy, 1937.

Krishnaswami, V. D. Stone Age in India, Ancient India, No. 3, (Jan., 1947).

Leakey, L. S. B. The Stone Age Cultures of Kenya Colony, London, Man, No. 66.

Logan, A. C. Old chipped stone of India, Calcutta, 1906.

Lydekker, R. D. Siwalik Fossils, *Palaeontologia indica*, Series X, **I**, 1874; **II** to **IV** : 1875–77.

Majumdar, D. N. Races and Cultures of India, Quoted Zeuner, on p. 21.

Mitra, P. Pre-historic India, Calcutta, 1927.

Moir, J. R. *Nature*, London, **149** : 77, 1941.

National Research Council, U. S. A. Report, Committee on Measurement of Geologic Time, 1937.

Nesturkh, M. The Origin of Man, Moscow, p. 210 ; 240–245, 1959.

Osborn, H. F. Man of the Stone Age, New York, 1915.

Okladinov, A. and Gerasimov, M. M. Teshik Tash grotto *Moscow*, , 1940.

Paterson, T. T. *Natnre*, London, **146** : 49, 1940.

Pilgrim, G. E. Tertiary Fresh Water Deposits of India. *Record Geol. Sur. of India*, **XL**, Pt. III, 1910.

——— Correlatian of the Siwalik Mammals, *Rec. Geol. Sur. of India.* **XLIII**, Pt. 4, 1913.

——— New Siwalik Primates and their bearings on the Questions of the Evolulion of Man and Anthropoids, *Rec. Geol. Sur. Ind.* **XLV**, 1915.

Sollas. Ancient Hunters, New York, 1924.

Smith Elliot. The Evolution Man : Early Man, his Origin, Development and Culture, London, 1931.

Taylor, G. Racial Geography, in "Geography in the Twentieth Century", Toronto, 230, 1949.

Taylor G. Climatic Cycle and Evolution, *Geographical Rev.*, New York, 1919.

——— Ecological Basis of Anthropology, *Ecology*, Chicago, 1934.

Taylor Griffith. Enviroument, Race and Migration, Toronto, 157-60, 1949.

Terra, de H. and Paterson, T. T. Studies of the Ice Age in India and Associated Cultures, Washington, 1939.

Verneu, R. La Grotte des Enganto, *Menton*, 1906.

Wadia, D. N. Geology of India, London, 368, 376–383, 1953.

Weidenreich, F. *Transac. Amer. Philosophical Soc.*, 31, 1941.

——— Palaeontologica Sinica, 1942, New Series, D. No. 10.

——— Giant Early Man from Java and South China, *Anthrop. Papers, Amer. Mus. Nat. Hist.*, **40** : Pt. I, 1945.

——— Apes, Giant and Man, Chicago, 1947.

Yefimenko, P. Stone tools from Kiik-Koba grotto, *Moscow*, 1953.

Zeuner, F. E. *Geol. Mag.*, London, **72** : 350, 1935.

——— *Proceedings Prehist. Soc.*, London, No. 8, 1937.

——— The Pleistocene Period ; Its climate, Chronology and its Faunal Succession, 1945.

——— Dating the Past, (Mathuen) London, 1950.

——— Quoted by D. N. Majumdar in Races and Cultures of India, 21, 1957.

FUNCTIONAL ANATOMY OF THE DIGESTIVE ORGANS OF FRESH-WATER TELEOSTS : PART III--ALIMENTARY CANAL OF *EUTROPIICHTHYS VACHA* (HAM.) (SILUROIDEA : SCHILBEIDAE)

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Introduction :

There are not many systematic accounts of the morphological and histological differences in the digestive organs of a carnivorous, omnivorous and herbivorous fresh-water fishes of India.

The important contributions which have appeared in the last quarter of a century on the alimentary canal and its associated structures of fishes are by Suyehiro (1942), Al-Hussaini (1945, 1946, 1647*a*, *b*, 1949*a* and *b*.), Al-Hussaini and Kholy (1953), Islam (1951), Girgis (1952), and Weinreb and Bilstad (1955). In India only a few fishes have been worked out so far. Dharmarajan (1936) has described the anatomy and histology of digestive system of *Otolithus ruber* ; Vanajakshi (1938) on the histology of the digestive tract of *Saccobranchus fossilis* and *Macrones vittatus* ; Sarbhai (1940) on *Labeo rohita* ; Mohsin (1944–46 and 1946) of *Anabas testudineus* and *Glossogobius giuris* ; Mahadevan (1950) of *Caranx djedaba* and *Trichiurus haumela* and *Mugil crenilabis* (1954) ; Kapoor (1953) of *Wallago attu* ; Das and Moitra (1956) on the comparative anatomy of the alimentary tract and its modifications in relation to feeding habits in *Labeo rohita*, *Labeo gonius*, *Puntius sophore*, *Eutropiichthys vacha*, *Notopterus notopterus*, *Ophicephalus striatus* and *Bagarius bagarius* ; Nagar and Khan (1958) of *Mastacembelus armatus* ; Sahgal (1960) on the anatomy and histology of the alimentary canal of *Mystus seenghala* with notes on its feeding habits ; Chitray and Saxena (1962) on *Heteropneustes fossilis* and *Clarias batrachus* ; and Chitray (1962) on *Bagarius bagarius*. The present work has been undertaken to make a comparative study of the differences between the gross anatomy of the alimentary canal of some fresh-water fishes of India with varied feeding habits. The functional anatomy of the digestive organs of a fresh-water teleost, *Eutropiichthys vaccha* (Hamilton), has been described in the present paper.

Material and Method :

A large number of dissections were made on fresh and preserved specimens for the study of the anatomy of the alimentary canal and its associated structures. A median longitudinal incision was given to the entire alimentary canal to examine the arrangement of the epithelial linings. Microscopical anatomy of different types of teeth in the bucco-pharyngeal cavity was studied both on fresh and permanent preparations.

Anatomy of the alimentary canal :

The alimentary canal of *E. vacha* (Fig. 1) is an uniformly straight tube which begins at the mouth and extends backwards throughout the length of the visceral

cavity and opens to the exterior through the anus, situated ventrally between the pelvic fins. It can be distinguished into the mouth, bucco-pharyngeal cavity, oesophagus, stomach, intestine and rectum. The rectum is not well defined externally from the posterior region of the intestine.

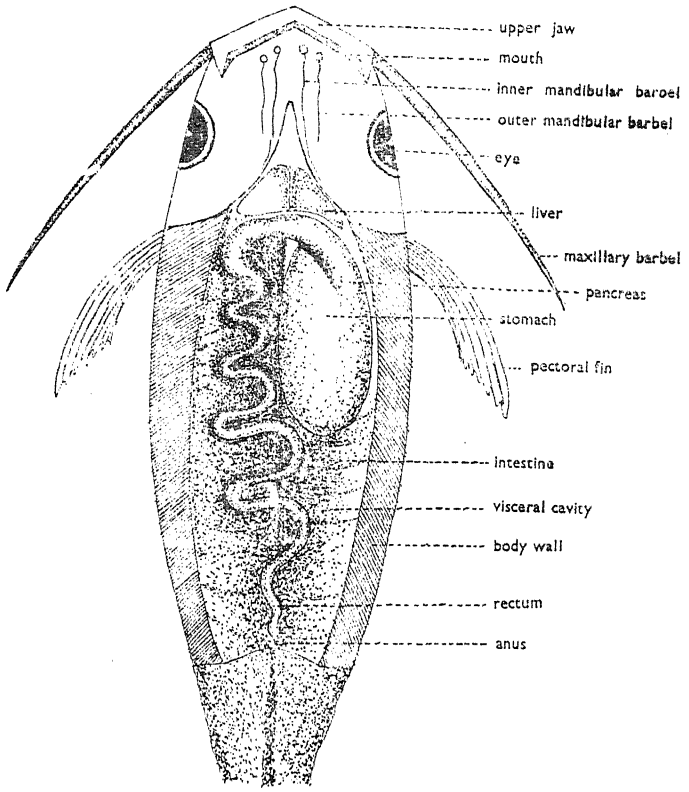

Fig. 1. Ventral view of fish showing the alimentary canal.

The coeliac, anterior and posterior mesentric arteries (Fig. 2) supply blood to the alimentary canal. The coeliac artery arises immediately after the junction of the fourth efferent artery with the dorsal aorta. Just after its origin from the dorsal aorta, it divides into two : the anterior supplies the oesophagus and the stomach, and the posterior supplies the anterior region of the intestine. The anterior mesentric artery supplies blood to the middle region and partly to the posterior region of the intestine. The posterior mesentric artery supplies to the posterior region of the intestine and rectum. The blood from the different parts of the alimentary canal is collected by a series of smaller veins constituting the 'hepatic portal system'. The hepatic portal vein enters the liver lobe from the right hand side. The intestine of other cat-fishes, *Heteropneustes fossilis* and *Clarias batrachus* (Chitray and Saxena, 1962) is considerably shorter than *E. vacha*, which is an omnivorous as reported by Das and Moitra, 1956 (Table 1).

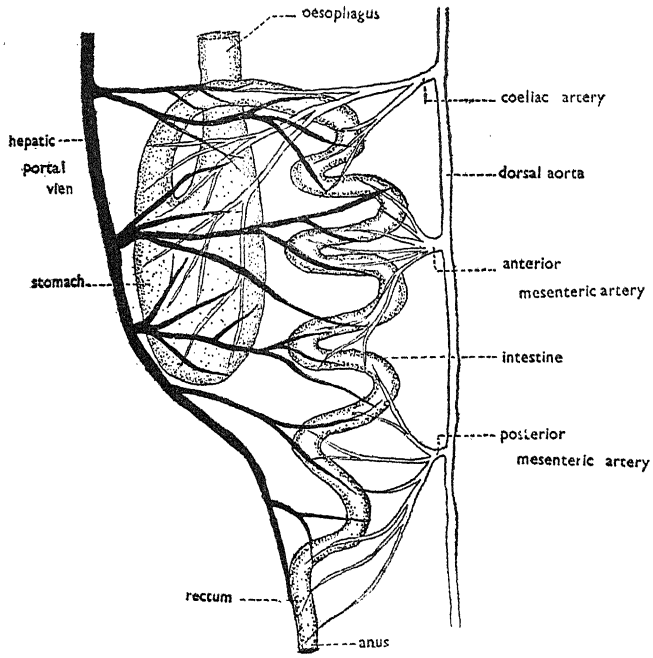

Fig. 2. Distribution of the blood to the gut.

TABLE I

Heteropneustes fossilis			*Clarias batrachus*			*Eutropiichthys vacha*		
Length of Fish (mm)	Length of Gut (mm)	Length of Intestine (mm)	Length of Fish (mm)	Length of Gut (mm)	Length of Intestine (mm)	Length of Fish (mm)	Length of Gut (mm)	Length of Intestine (mm)
156	168	142	152	115	90	154	247	214
190	260	232	196	136	107	191	372	337
170	175	148	164	119	98	181	312	275
176	182	155	171	130	102	185	292	249
230	326	308	230	157	124	221	322	270
260	362	342	290	201	176	282	364	310

* Chitray and Saxena (1962).

Barbels, mouth and lips :

There are four pairs of barbels (Fig. 3) (*a*) Nasal, (*b*) Maxillary, (*c*) Outer mandibular, and (*d*) Inner mandibular. The maxillary pair of barbels are the longest and reach upto the end of the pectoral fin or even further. Inner mandibular is longer than the outer one and the nasal is the smallest being a simple filamentous structure.

The mouth is sub-terminal due to the protrusion of the upper jaw and is bounded by soft upper and lower lips.

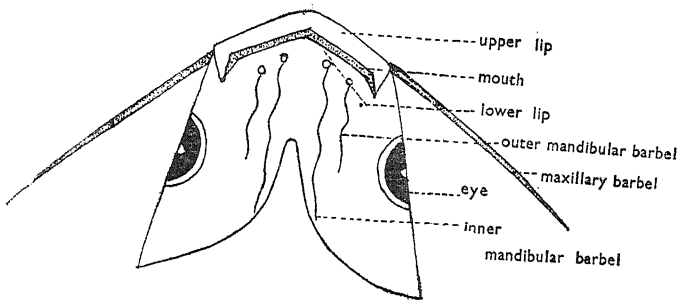

Fig. 3. Ventral view of the fish showing the position of the mouth and the barbels.

Bucco-pharyngeal cavity :

The buccal cavity is narrow anteriorly and wide posteriorly. It extends from the mouth upto the first gill-slit. The pharyngeal cavity includes the branchial region as well as the region of the pharyngeal teeth. It is wide anteriorly and narrows down posteriorly. The base of the cranium forms the roof of the bucco-pharyngeal region while the sides and the floor are supported by the branchial arches and median urohyal respectively. The mucosal thickening at the anterior part of the floor is suggestive of a tongue-like structure.

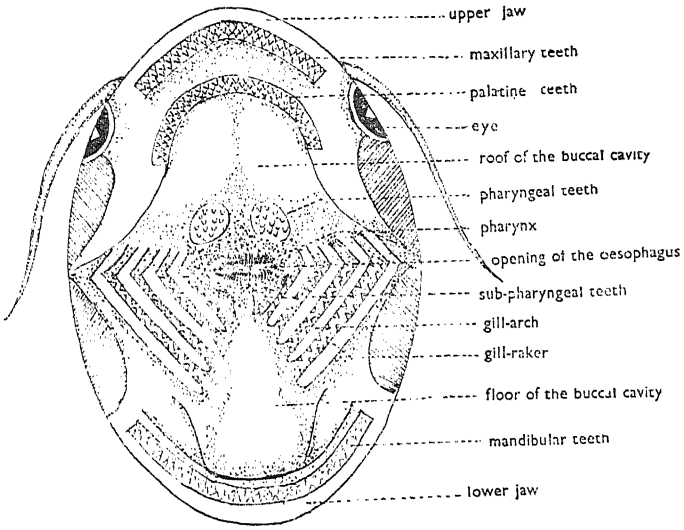

Fig. 4. A diagrametic representation of the bucco-pharyngeal cavity showing the different groups of teeth.

There is no line of demarcation between the anterior buccal and posterior pharyngeal region, except for the presence of the pharyngeal teeth in the later. In the bucco-pharyngeal cavity (Fig. 4) the teeth are disposed in several groups and destined to perform a particular function.

I. Teeth on the roof of the bucco-pharyngeal cavity are :
(*i*) Maxillary teeth, (*ii*) Vomerine teeth, (*iii*) Pharyngeal teeth.

II. Teeth on the floor of the bucco-pharyngeal cavity are :

(*i*) Mandibular teeth, (*ii*) Sub-pharyngael teeth.

The teeth in the bucco-pharyngeal cavity are homodont and all are pointed backwards. They are slightly inclined in such a manner that the teeth of one side of the buccal cavity face those of the other side, so as to hold the slipping prey in an efficient manner, as also for biting and rasping the prey. All the teeth are fixed by fibrous ligaments to the underlying gum-like fleshy lobes. A typical tooth (Fig. 5) has a pointed apex and a broad base. Maxillary and mandibular teeth are very prominent and largest of the series, in comparison with those of the pharyngeal and sub-pharyngeal teeth (Das and Moitra, 1956 have reported them as Horny Pad Teeth), which are smaller. The pharyngeal teeth are borne on a pair of oval patches. The sub-pharyngeal teeth are also present in two oval pads on the floor of the bucco-pharynx and serves the function of rasping the prey. The vomerine teeth (Das and Moitra, 1956 have reported them as Palatine Teeth, but the author has found them shifted on the vomer) are present in *E. vacha* as in *C. batrachus* and *H. fossilis*. Thus the dentition is highly specialised for rasping the food.

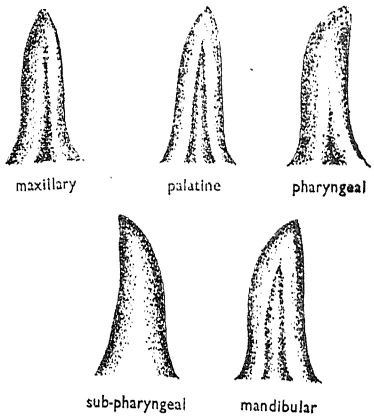

Fig. 5. Different types of teeth in the bucco-pharyngeal cavity.

The gill-rackers (Fig 6) are hard, thick and pointed structures. They are fairly long so as to provide additional hold for gripping the prey. The teeth are not used for mastication and the food material has been observed entering the oesophagus entire.

The epithelial lining of the bucco-pharyngeal cavity is smooth without any fold. A few longitudinal and wavy folds are present in the anterior region in between the patches of the pharyngeal teeth, which continue posteriorly into the oesophagus.

Oesophagus :

The pharynx leads into the oesophagus which is tubular extending posteriorly, ventral to the pericardial chamber, and after passing through the septum

transversum emerges into the visceral cavity. In the visceral cavity it passes dorsally to the lobes of the liver.

The mucosal epthelial folds (Fig. 7) increase in height and in number considerably than those present in the posterior region of the bucco-pharygeal cavity, but the height goes on decreasing as the oesophagus approaches the stomach.

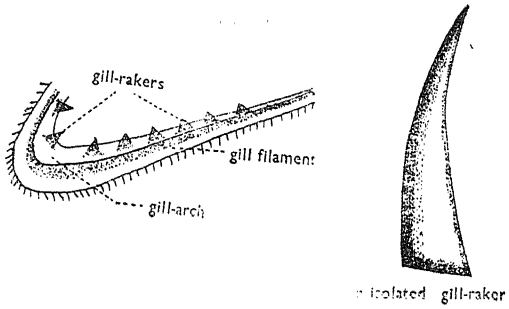

Fig. 6. (*a*) A single gill-arch.
(*b*) An isolated gill-raker.

Stomach :

It is true sac-like stomach and is a large organ situated ventrally slightly in the left side of the visceral cavity. It is distinguishable into three regions : proximal part, the 'Corpus' or the 'Body', the distal blind sac or the 'Caecum', and the 'Mesial' the pyloric region.

The mucous membrane of the stomach (Fig. 8) is smooth dorsally and disposed ventrally in the longitundinal zigzag folds. They are prominent in the pyloric region. The mucosal folds of the pyloric region are conspicuous and differ from the oesophageal folds, and are distributed in a haphazard manner.

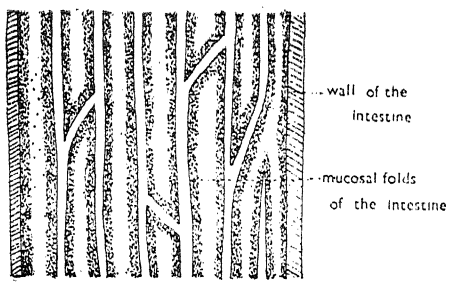

Fig. 7. Mucosal folds of the oesophagus.

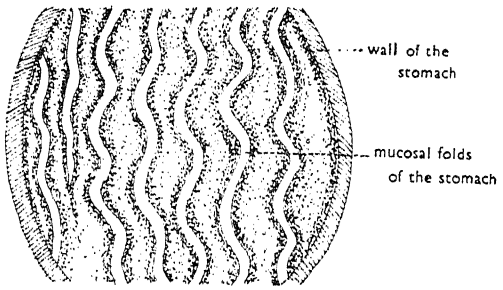

Fig. 8. Mucosal folds of the stomach.

Intestine :

The intestine takes its origin from the conical pyloric end of the stomach (Fig. 9). It is much constricted and forms a narrow passage into which the mucosal folds of the stomach diminish in size. The intestine cannot be differentiated into different regions externally owing to lack of any demarcation. A very slight variation in diameter and in the disposition of the mucous membrane occur throughout the intestine, otherwise it is almost the same in diameter throughout

its length except near the rectum where it is slightly less in diameter than that of the rest.

The mucosal folds of the intestine (Fig. 10) are not prominent in any part of the intestine. But a microscopical examination gives a web-like appearance, showing the mucosal folds to be of very small size and are forming small crypts.

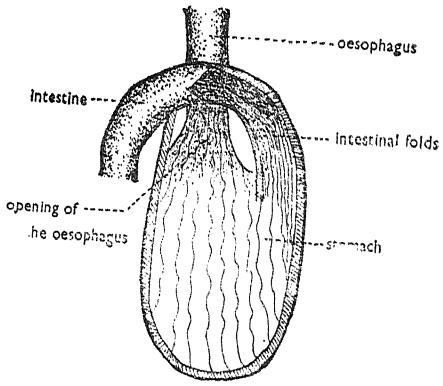

Fig. 9. Mucosal folds of the part of the stomach and intestine showing pyloric constriction.

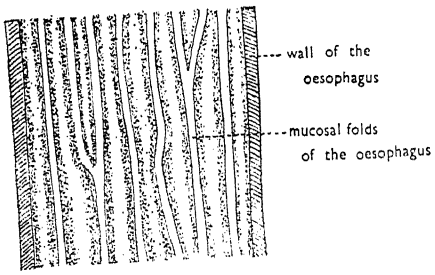

Fig. 10. Mucosal folds of the intestine.

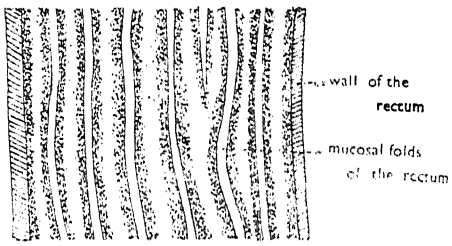

Fig. 11. Epithelial lining of the rectum.

Rectum :

It is not distinguishable from the intestine either externally or internally. The posterior end (Fig. 11) of the intestine in which the mucosal folds are a bit prominent and longitudinal, be called as 'rectum' which opens exteriorly through anus.

Digestive glands :

Liver.—The liver of *E. vacha* is a bilobed, light brown compact gland (Fig. 12) distinguishable into right and left lobes. The right lobe is smaller than the left one. It is lodged in the visceral cavity above the stomach and occupies a considerable area of the abdominal cavity. In between the right and left lobe on dorsal side lies the pitcher-shaped gall-bladder. It is greenish-blue in colour owing to the presence of bile, which can be seen through its transparent thin walls. A cystic duct emerges out of the gall-bladder anteriorly and goes forward by the side of the left hepatic lobe for a short distance and receives right and left hepatic

ducts from the right and left sides of the liver respectively (Fig. 13). The bile-duct, so formed, runs forwards for some distance along with the pancreatic duct. Now the hepatic and pancreatic ducts enter dorsally on the right side of the anterior part of the intestine. They run as two separate ducts and open into the lumen of the intestine by two separate openings lying close together.

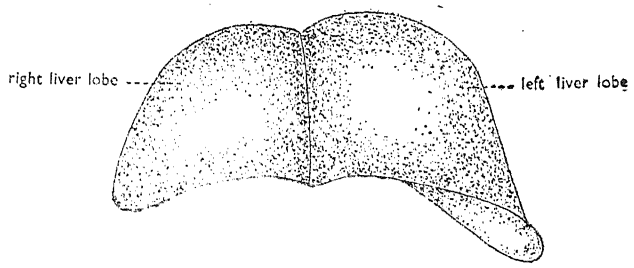

Fig. 12. Ventral view of the liver.

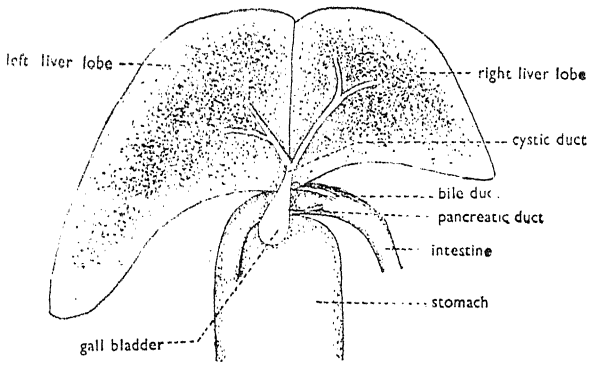

Fig. 13. Dorsal view of the liver with Gall-bladder along with cystic duct, bile and pancreatic ducts.

Pancreas.--The pancreas is a diffuse structure and is scattered over the stomach and also extends over the surface of the intestine (Fig. 1) along with the portal vessels. Pancreatic ductules join to form the median pancreatic duct which opens in close approximation (Figs. 13 and 14) with the opening of hepatic duct into the proximal part of the intestine.

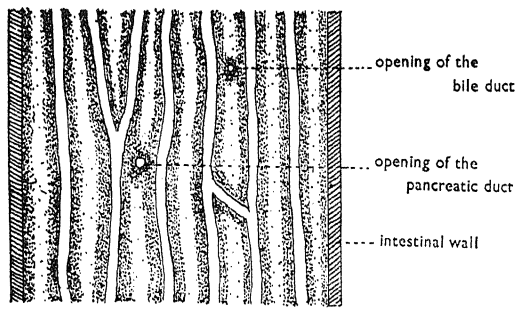

Fig. 14. Anterior part of the intestine showing the openings of the bile and pancreatic ducts.

Discussion ;

The adaptation of the digestive organs of the fish to its normal food is mainly demonstrated in the form of mouth, size, shape and structure of the bucco-pharyngeal cavity, the dentition, the gill-rackers, the stomach, the intestine and also the relation between the length of the gut and the standard length of the fish which are subject to much modifications.

The mouth of *E. vacha* is small and inferior. Its snout is broader and flattened. In the bucco-pharyngeal cavity there are five sets of homodont backwardly pointed teeth. They are arranged so that they hold efficiently the slippery prey and are also used for biting and rasping the prey. The teeth are not used for mastication. Das and Moitra (1956) have shown that the teeth which are localised in the bucco-pharyngeal region of *E. vacha*, make it a well equipped zone for holding the prey in an efficient manner, as also for biting and rasping the prey. Al-Hussaini and Kholy (1953) have also given the similar account of *Clarias lazera*.

Das and Moitra (1956) have shown that the gill-rackers in omnivorous fishes are stout, thick, comparatively hard and fairly long pointed structures and are provided for additional hold of gripping the prey. Al-Hussaini (1947*b*), and Al-Hussaini and Kholy (1953) have described the gill-rackers in *Clarias lazera*, *Tilapia nilotica* and *Sargus vulgaris* of the same nature as stated above and seem to have a two fold function, one of the protection and the other of food retention. In *E. vacha* the gill-rackers are also of the same type to serve the same function.

The epithelial lining of the bucco-pharyngeal cavity in *E. vacha* has no fold and is smooth. Only a few wavy folds are present in the posterior region. The entire alimentary canal is thick-walled, muscular and elastic. The adaptation to omnivorous condition is also supported by the presence of teeth, specialised for grasping the aquatic plants and holding the prey. The oesophagus, stomach, intestine and rectum have prominent mucosal folds. These folds are longitudinal in oesophagus, zig-zag longtiudinal course in the stomach and in the anterior part of the intestine. They again become longitudinal in the posterior region of the intestine and with a few inter-connections which become straight in the region of the rectum. Al-Hussaini and Kholy (1953) have given a similar account in omnivorous fishes, *C. lazera*, *T. nilotica* and *S. vulgaris*.

The surface area of the gut depends on the length of the gut as well as the foldings of its lining membrane. Das and Moitra (1956) observed that the relative length of the gut alone showed a well marked deviation from herbivorous towards carnivorous condition of the almentary canal. Pillay (1953) observed in *Mugil Tade* Forskal, length of the alimentary canal varies with the nature of the food consumed in different environments. Das and Moitra (1956) have also shown that a constant ratio exists between the gut length and total body length for each species of fish in a large number of food fishes of Uttar Pradesh from the same water sources. The relative length of the gut of *E. vacha* is 0·43.

Al-Hussaini (1949) in *Rutilus rutilus* ; Al-Hussaini and Kholy (1953) in *C. lazera*, *T. nilotica* and *S. vulgaris* ; Das and Moitra (1956) have reported that the food, of *E. vacha* the omnivorous fish, consists of unicellular algae, filamentous algae, higher aquatic plants, rotifers, insects and their larvae, crustaceans, mud and sand. Present observations on the alimentary canal show that it is adapted for an omnivorous diet.

Summary :

This paper deals with the anatomical structures of the digestive organs of *Eutropiichthys vacha*. There are four pair of barbels. The alimentary canal can be distinguishable into mouth, bucco-pharyngeal cavity, oesophagus, stomach, intestine and rectum. The mouth is sub-terminal. Five sets of teeth are present. The mucosal folds in the oesophagus are quite prominant. The stomach is muscular and true sac-like structure can be distinguished into three regions. The intestine is not well marked into different regions either externally or internally. The liver is a well-developed, bilobed structure. The pancreas is a diffuse structure.

Acknowledgments :

I am very grateful to Dr. D. B. Saxena, Department of Zoology, D. A. V. College, Kanpur, for his keen interest and guidance, and timely criticim during the preparation of this paper. My sincere thanks are also due to Shri J. M. Lal, Principal, H. S. J. S. College, Kanpur for his kind permission to work in the College Laboratory.

References :

Al-Hussaini, A. H. The anatomy and histology of the alimentary tract of the bottom-feeder, *Mulloides auriflemma* (Forsk). *J. Morhp. Philadelphia*, **78** : 121–153, 1945.

——— The anatomy and histology of the alimentary tract of the coral-feeder fish, *Scarus Sordidus* (Klung). *Bull. Inst. Egypt*, **27** : 349–377, 1947.

——— The anatomy and histology of the alimentary tract of the plankton-feeder, *Atherine forskali*, Rupp. *J. Morph. Philadelphia*, **80** : 251–286, 1947.

——— On the functional morphology of the alimentary tract of some fish in relation to difference in their feeding habits ; Anatomy and Histology. *Quart. J. Micros. Sci.*, **90** (2) : 109–140, 1949.

Al-Hussaini, A. H. and Kholy, A. A. On the functional morphology of the alimentary tract of some omnivorous fish. *Proc. Egypt. Acad. Sci.*, **9** : 17–39, 1953.

Chacko, P. I. On the food of the alimentary canal of Milk-fish, *Chanos chanos*. *Curr. Sci.*, **14** : 242–243, 1945.

Chitray, B. B. and Saxena, D. B. Functional anatomy of the digestive organs of the fresh-water fishes of India : *Heteropneustes fossilis* and *Clarias batrachus*. *Acta Societatio Zoologicae Bohemoslovenicae, Czechoslovakia.* **26** (2) : 148–159, 1962.

Chitray, B. B. Functional Anatomy of the digestive organs of a fresh-water fish of Uttar Pradesh (India) : *Bagarius bagarius* (Ham.) *Proc. J. Zool. Soc. India*, **14** (1) : (In press), 1962.

Das, S. M. and Moitra, S. K. On the correlation between the fish food and fish gut in food fishes of U. P. *Proc. 42nd Indian Sci. Cong.*, **IV** : 10, 1956.

——— Studies on the food of some common fishes of Uttar Pradesh (India) Part III, 'Comparative anatomy of the alimentary tract and its modifications in relation to feeding habits'. *Pro. Nat. Acad. Sci. India*, **XXVI** (B) IV : 224–233, 1956.

Girgis, S. On the anatomy and histology of the alimentary tract of herbivorous bottom-feeding Cyprinid fish, *Labeo horie* (Cuvier). *J. Morph.*, **90** (2) : 317–362, 1952.

Girgis S. The bucco-pharyngeal mechanism in a herbivorous bottom-feeding Cyrinid, *Labea horie* (Cuvier). *Ibid.*, **90** (2) : 281–315, 1952.

Greene, C. W. Anatomy and histology of the alimentary tract of King Salmon, *Oncorhynchus tschawytscha*. *Bull. U. S. Burean, Fish*, **32** : 73–100, 1912.

Islam, A. U. The comparative histology of the alimentary canal of certain fresh-water teleost fishes. *Pro. Indian Acad. Sci.*, **33** (2) : 297–32, 11951.

Kapoor, B. G. The anatomy and histology of the alimentary canal in relation to its feeding habits of a siluroid fish, *Wallago attu* (Bl. and Schn.). *J. Zool. Soc. India*, **5** (2) : 191-210, 1953.

Mahadevan, S. The digestive system of *Caranx djedaba* (Forsk) and *Trichiurus haumela* (Forsk). *J. Madras Univ*, **21** (B) : 25–48, 1950.

——— The digestive system of *Mugil crenilabis* (Forsk). *Ibid.*, **24** (*b*) : 143–160, 1954.

Mohsin, S. M. The morphology and histologe of the alimentary tract of *Anabas testudineus*. *J. Os. Univ. (Sci. Faculiy)*, **12** : 66–75, 1944-46

——— Histology of the alimentary tract of a fresh-water goby, *Glossogobius giuris* (Ham.) *Proc. Indian Science Cong.*, **III** Abstact, 1946.

Mookerjee, H. K. and Ganguly D. N. Pharyngeal teeth in relation to food babits of fresh-water fishes. *Ibid.*, **III**, Abstact. 1945.

Nagar, S. K. and Khan, W. M. The anatomy and histology of the alimentary canal of *Mastacembelus armatus* (Lecep.) *Proc. Indian Acad. Sci.* **47**-3B : 173–187, 1958.

Pillay, T. V. R. Studies of the Food, feeding habits and alimentafy canal of grey mullet, *Mugil tade* (Forsk). *Proc. Nat. Inst. Sci. India* **19** (6) : 777–827, 1953.

Sahgal, P. The anatomy and histology of the alimentary canal of *Mystlus seenghala* (Sykes) with notes on its feeding habits. *Res. Bull. Punjab Uni.* **11** (1/2) : 77–86, 1960.

Sarbhai, D. S. The alimentary canal of *Labeo rohita* (Ham.) *J. Royal Asiatic Soc. Bengal Sci.* **5** (2) : 88–116, 1940.

Sharma, M. S. and Chandy, M. Studies on the alimentrry tract in relation to its feeding habits in Feather Back, *Notopterous chitala* (Ham.) *Pooc. 48th Indian Sci. Congr.* **III**, Abstract, 1961.

Suyehiro, Y. A study on the digestive system and feeding habits of fish. *Jap. J. Zool.*, **10** (1) : 1-303, 1942.

Vanajakshi, T. P. Histology of the digestive tract of *Saccobranchus fossilis* and *Macrones vittatus*. *Proc. Indian Acad. Sci.* **7**-B : 61–79, 1938.

Weinreb, E. L. and Bilstad, N. M. The histology of the digestive tract and adjacent structures of the rainbow trout, *Salmogairdneri irideus*. *Copeia*, **3** : 194–204, 1955.

FLORAL ANATOMY AND GAMETOPHYTES OF *HIBISCUS MICRANTHUS* LINN.

By

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[Received on 18th June, 1962]

Hibiscus micranthus Linn. belongs to the tribe Hibisceae of the family Malvaceae. Although the members are economically important, as lint and fibre producing plants, yet the morphological investigations are far from adequate. The female gametophyte, pollen growth and fertilization were studied in *Hibiscus trionum* and *Althea rosea* by Guignard (1904). Balls (1905) studied the development of floral organs, embryo sac, microspore and fertilization in *Gossypium*. The development of female gametophyte was also investigated by Gore (1932) and Yamaha (1926), in species of *Gossypium*. Medvedava (1944) and Banerji (1942) studied embryologically *Hibiscus cannabinus* and *Bombax malabaricum* respectively. Floral anatomy of the several members of the family have been also studied (Gundersen, 1938 ; Rao, 1952). Cytological studies were done by Denham (1924) and Beal (1928) in *Gossypium barbadense* L.

Present investigation deal with the floral anatomy and the development of male and female gametophytes of *Hibiscus micranthus* Linn., which is a promising fibre yielding plant.

Methods and Material :

The material collected from Ajmer and Nasirabad (Rajasthan) was fixed in Acetic-alcohol. It was dehydrated, cleared and infilterated by the tertiary butyl alcohol-paraffin method. Difficulty in cutting was encountered due to the presence of copious hairs on various parts of the flower which were softened with hydrofluoric acid.

Longitudinal and transverse sections, 6–16 microns in thickness were cut and stained in iron-alum-haemotoxylin and Orange G ; safranin and fast green ; Gentian violet and erythrosin.

Organogeny :

The floral organs develop in acropetal succession. The first whorl to develop is of bracteoles (epicalyx) while the carpel whorl is the last to develop. In the earlier stages the carpellary margins grow inwards and fuse laterally but do not meet in the centre so that the ovary remains unilocular. But in older stages the margins of the carpels fuse to form the axile placentation.

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Flower :

Flowers are axillary, hermaphrodite and pentamerous. There are sixe to eight bracts in epicalyx, which are free from one another and also from sepals. Aestivation of sepals and petals is valvate and twisted respectively. The petals are adnate to the base of staminal tube of indefinite and monadelphous stamens. Anthers are monothecous—a distinguishing character of the family. Staminal tube terminates in five non-vascular teeth, representing sterile prolongations of the members of antipetalous staminal whorl (Saunders, 1937). The gynaecium is pentacarpellary, syncarpous and pentalocular with three ovules in each locule. Pentafid stigma is covered with glandular hairs. The glandular hairs are also present on the sepals and the wall of the ovary.

Secretory cells are of common occurrence in all the parts of the flowers especially in the sepal region and in the staminal tube. Their cell walls fuse to form wide canals.

Floral Anatomy :

The lower region of the flower pedicel shows a ring of six to eight somewhat unequal endarch, collateral vascular bundles (Figs. 1, 2). Many mucilaginous canals are present in the pith and cortex. Such canals are of common occurrence in all parts of the flower. The vascular bundles increase in number by division and tend to form a closed ring. From these the traces for bracteoles are given out (Fig. 3). A single trace enters each bracteole (Fig. 4). After the emergence of bracteole traces, ten traces are given out for the sepals (Figs. 3, 4) breaking the receptacular stele into bundles in which the xylem begins to fade out. The ten vascular bundles supplied to the sepal region are the five dorsals and the five fused marginals of the sepals.

Further, from the receptacular stele five conjoint petal-stamen traces are given out (Figs. 4–6), which are alternate to the sepal traces. These traces get tangentially stretched and become lobed. Almost at the joint of petal-stamen tube the conjoint bundles split into separate petal and staminal bundles which later diverge from each other and enter the respective organs. In the formation of the last series of stamens, the bundles bend out bodily into the free filaments and the tube terminates into five non-vascular teeth.

After the separation of petal-stamen traces, the receptacular stele comprises of bundles placed in two rings (Fig. 5). The outer ring consisting of five bundles become the five dorsals of the carpels. The inner ring which in the beginning consists of six to eight, divide and curve towards periphery functioning ventrals and medium laterals. The ovules are supplied by the ventrals.

The bundles which are traversing the wall of the ovary fade out towards the top while ventrals continue their course forming a ring in the style. Higher up these also fade out and the core of style develops conducting tissue. This tissue breaks up into five tracts, each of which enters in one of the stigmatic branches at the top of style.

The axile placenta is formed by the fusion of the margins of the different carpels, and the ventral bundles never move in the central axis. So the ventrals are placed on different radii, not oposite the dorsals.

Microsporogenesis and Male Gametophyte :

A cross section of the young anther shows a mass of meristematic tissue. This soon becomes lobed and in each lobe a cell in hypodermal position becomes differentiated due to their larger size and consipicuous nuclei. These archesporial cells

divide periclinally to form primary parietal layer and sporogenous cells (Fig. 9). Primary parietal layer divides by anticlinal and periclinal divisions to form three layers ; *endothecium*, a *middle layer* and *tapetum* (Fig. 10). The tapetal cell at maturity become usually binucleate, often four nucleate cells were also observed. Prior to dehiscence, the wall of anther consists of epidermis, endothecium, remanants of middle layer and tapetum. At the time of dehiscence the epidermis is found to be stretched and its walls lignified. The endothecium is well developed, the fibrous thickenings appear just after the completion of reduction division in the microspore mother cells.

Primary sporogenous cells undergo few mitotic divisions forming microspore mother cells. They are closely placed in the microsporangium and are polygonal in shape. These cells possess densely cytoplasm. Later they round off and separate, from each other. The microspore mother cells undergo reductional divisions (Fig. 12–15) and during the meiosis II differences in the orientation of spindles form various forms of tetrads, *i.e.*, tetrahedral (Fig. 10), isobilateral (Fig. 16). The division is of simultaneous type and quadripartition takes place by furrowing. After cytokinesis the unilocular pollen grains separate from one another.

Microspore has a prominent nucleus in the centre which is displaced towards periphery by vacuole (Fig. 17). The exine develops spines. The first division in the microspore results in the formation of a vegetative cell and a small generative cell. The generative cell is lenticular and is surrounded by dense cytoplasm. It come to lie near the vegetative nucleus (Fig. 18). The two loculi of the bisporaginate anthers eventually fuse to form a single loculus (Stenar, 1925 ; Maheshwari, 1950). Pollen grains are shed at the two celled stage as in most of the genera of the family. However, pollen grains with three cells were also found.

Ovule :

The campylotropous ovules (Fig. 20) are crassinucellate and bitegmic. Both the integuments take part in the formation of micropyle which has the usual zig-zag form characteristic of the order Malvales. The outer integument appears first followed by the inner integument. The growth of the former is faster and it covers the nucellus, earlier. The outer integument is two celled in thickness except at the micropylar end, while the inner integument is four celled in thickness. These layers of the integument increase as the ovule matures.

The massive nucellus is composed of more or less regularly arranged cells. It becomes six to eight cell in thickness before the megaspore mother cell divides (Figs. 21, 22). It grows further as the embryo sac develops but is absorbed eventually. The cells in the chalazal end become filled with tannin and stand out conspicuously in the mature ovules as in the several members of the family.

Megasporogenesis and Female Gametophyte :

The archesporium differentiates at the time when the integumentary primordia are not visible (Fig. 19). This takes place at the time of microspore formation in the anthers. The archesporial cell divides to form primary parietal cell and a megaspore mother cell. The former divides anticlinally and periclinally to form several wall layers (Figs. 20–22). The megaspore mother cell greatly increases in size. As the wall layers divide, the megaspore mother cell is pushed towards the chalazal end. It undergoes two meiotic divisions (Figs. 22, 23) resulting in the formation of four megaspores (Fig. 24) In addition to the usual linear tetrads, T-shaped tetrads are also not uncommon.

The chalazal megaspore functions and gives rise to the embryo sac. Functioning of the micropylar megaspore was also reported in *Gossypium* (Balls, 1905). Usually the chalazal megaspore functions in cotton (Gore, 1932). The funtional megaspore increases in size and vacuoles develop one on either side of the nucleus, while other degenerate. Last to degenerate is the micropylar megaspore. Cases of two young embryo sacs lying side by side in the same ovules were observed (Figs. 25, 26). Two tetrads lying side by side were also reported in *Eriodendron anfructosum* DC. (Thrimulachar and Khan, 1942). In *Bombax malabaricum* DC., two megaspores were seen in the same ovule (Banerji, 1942). After the first division in the embryo sac, a large vacuole is formed in the centre displacing the two nuclei to the two poles. Dense cytoplasm is aggregated around them. Two further successive divisions (Figs. 28, 29) in this, form the eight nucleate embryo sac. An interesting case with three nucleate embryo sac (Fig. 27) was also noted which shows the undivided micropylar nucleus. The female gametophyte conforms to monosporic, octanucleate, Polygnum type of embryo sac (Fig. 29).

The embryo sac is long and narrow in the middle region and becomes curved at maturity. The antipodals may lie in the linear file (Fig. 29) or one above and two below. The synergids like those of Sterculicacae and Tiliaceae are hooked, pyriform and have a basal vacuole. The two polar nuclei lie near each other and later move on towards the egg apparatus. Antipodals disappear early while synergids persist till fertilization. Early disappearance of antipodals and somewhat persistant synergids were also recorded in *Althea* and *Hibiscus* (Guignard, 1904) ; and in *Gossypium* (Guignard, 1904 ; Gore, 1932).

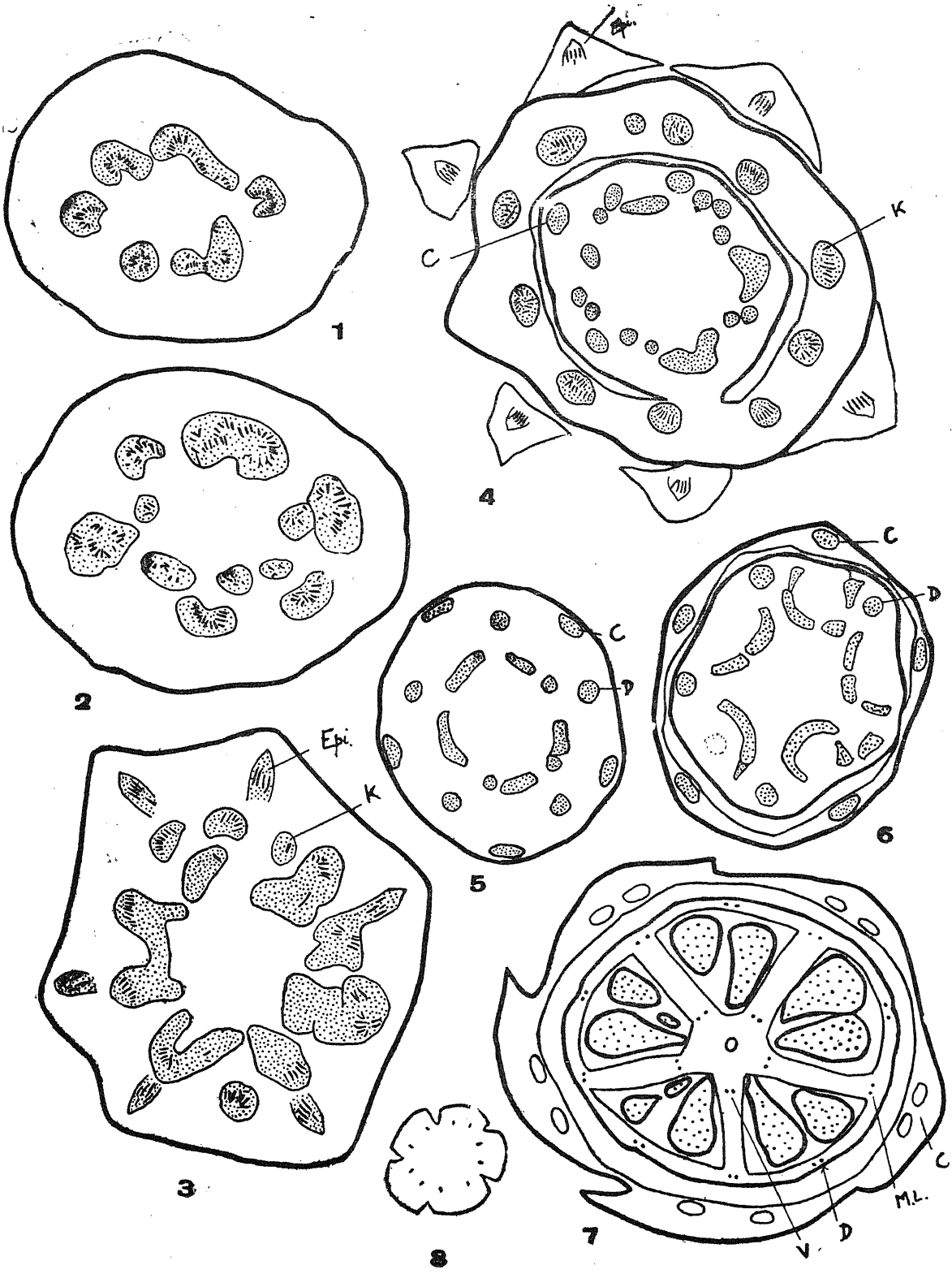
Discussion :

On the basis of genera like *Hibiscus*, Gundersen (1937) concluded that the axile placentation is evolved from the parietal (*cf.* Puri. 1952). Placentation in *Hibiscus micranthus* has been described as axile (Rao, 1952). Although the ovules are attached in the centre and the ovary is pentalocular, the placentation is not anatomically axile since the ventral strands are not placed opposite the dorsals, on the same radius. The anatomy therefore is that of a parietal placentation.

Anatomically, this species resembles with the other plants of the family. The conjoint petal-stamen trace is common in all the known members of the family (Rao, 1952).

Hibiscus micranthus Linn. shows several common embryological features of the family like, two celled pollen grains, bitegmic campylotropous ovules with zig-zag micropyle formed by both the integuments, massive nucellus, a zone of tannin bearing cells in chalazal, structure and development of the embryo sac, fusion of polar nuclei in later stages at the time of fertilization.

Edlin (1935) suggested that the tribe Hibisceae of the family Malvaceae should be transfered to the Bombacaceae. He claims that Hibisceae is a connecting link between the two families and resembles Bombacaceae in their capsular fruits. Anatomically, both differ from other tribes of the Malvaceae. Reeves (1936) and Davie (1937) however observed that Hibisceae has genera which have attained phylogenetically a much higher level of development than the members of other tribes of Malvaceae. The study of pollen grains also shows that Hibisceae possess the characteristic Malvaceous type of multiporate, spinescent grains which differ markedly from those of Bombacaceae which are uniformly triporate and smooth walled (Metcalfe and Chalk, 1950 ; Rao, 1952). It is, therefore suggested that the tribe Hibisceae is better placed under Malvaceae.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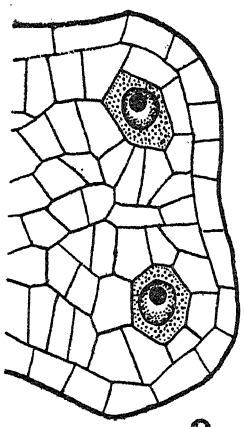

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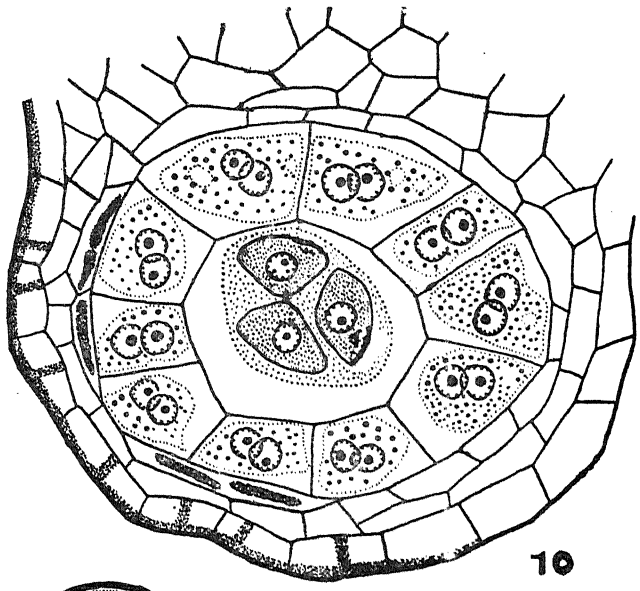

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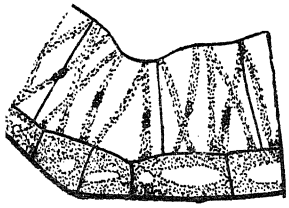

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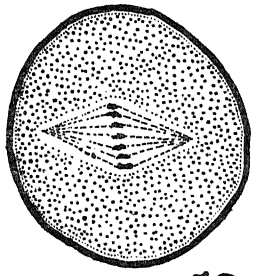

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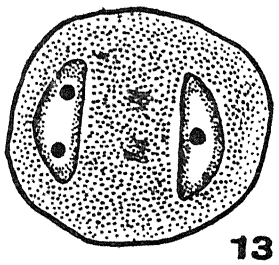

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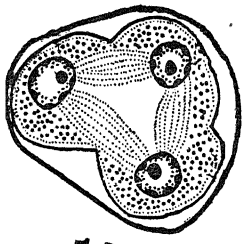

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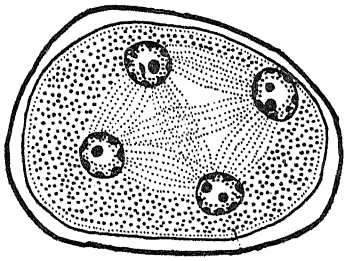

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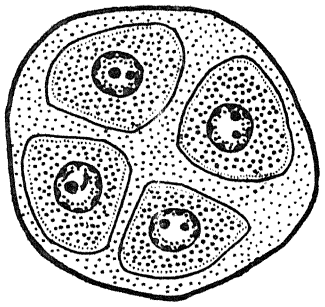

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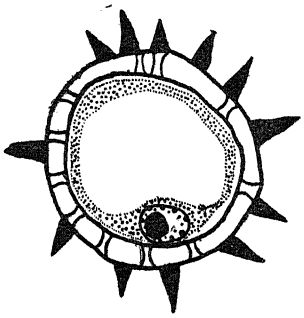

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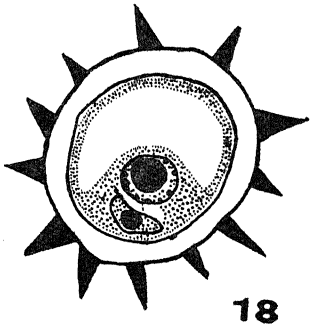

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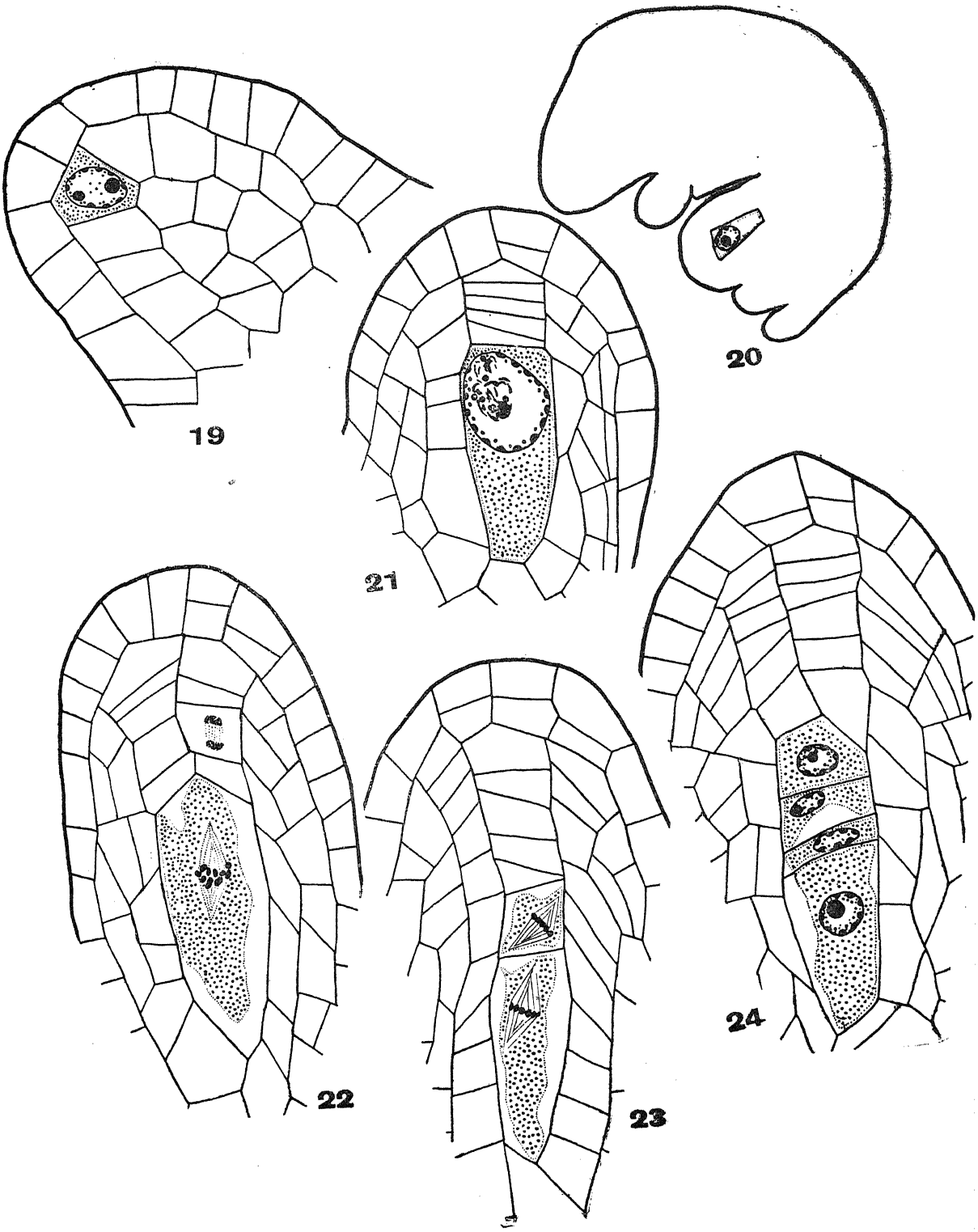
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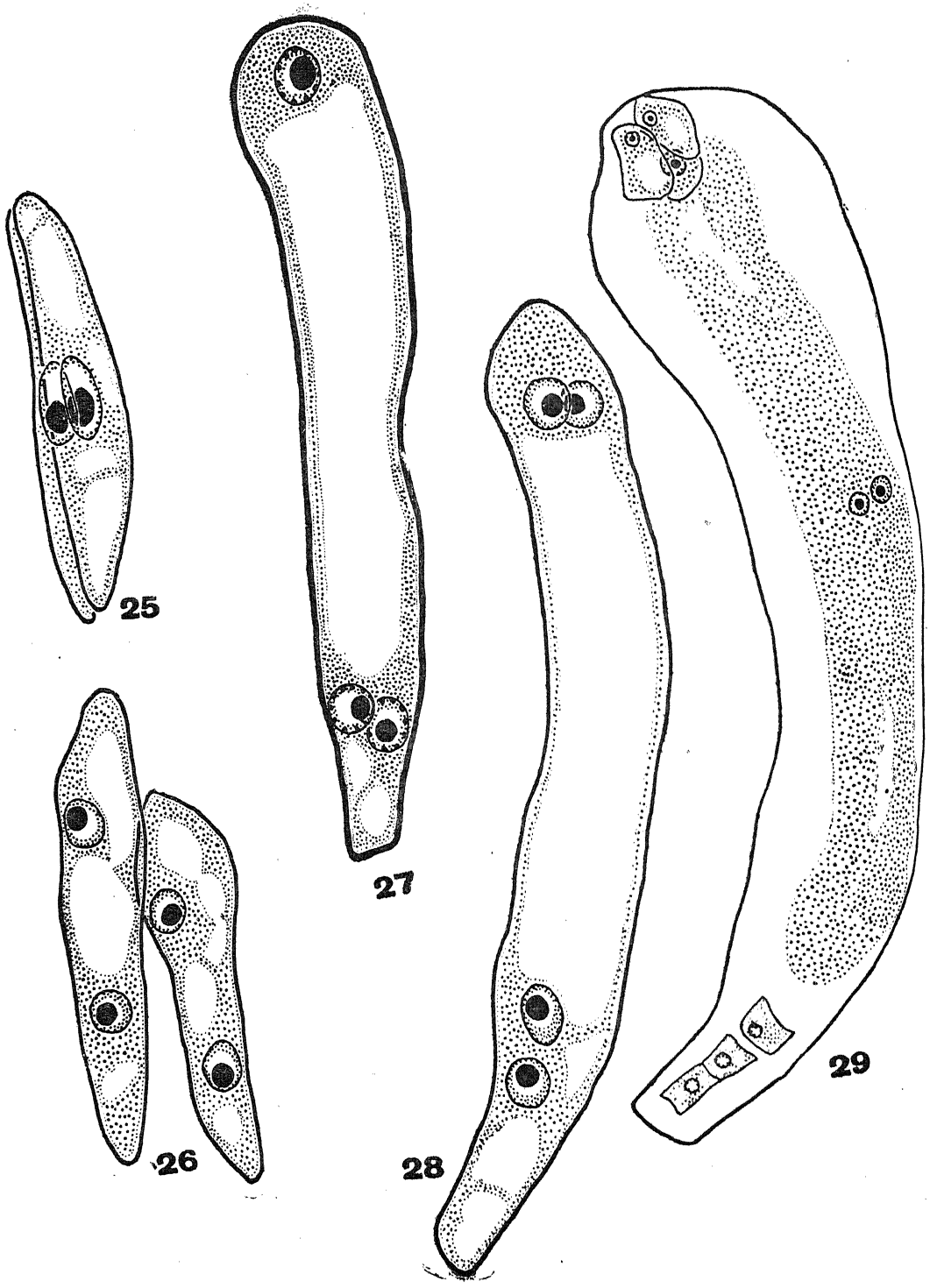
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LEGENDS

Figs. 1–18. *Hibiscus micranthus* Linn. *Anatomy of the flower and male gametophyte.* Figs. 1, 2. C.S. flower, receptacular stele ; Figs. 3, 4 same, epicalyx, calyx and bundles of corolla differeniating ; Fig. 5, same, corolla and dorsal bundles (calyx removed) ; Fig. 6, same, corolla, dorsal bundles and carpel bundles differentiating; Fig. 7, same, corolla, dorsals, medium laterals and ventrals ; Fig. 8, same, style ; Fig. 9, G.S. anther, sporogenous cells ; Fig. 10, C.S. one anther lobe showing wall layers, tapetum and microspores ; Fig. 11, epidermis and endothecium showing thickenings ; Figs. 12–15, reduction division I and II in the microspore mother cell ; Fig. 16, isobilateral tetrad ; Figs. 17, 18, uninucleate and bicelled pollen grains.

Figs. 1–7 X27 ; Fig. 8 X60 ; Figs. 9–11 and 17, 18 X370 ; Figs. 12–16 X613.

Figs. 19–29. *Megasporogenesis and development of female gametophyte.* Fig. 19, ovule, archesporium ; Figs. 20, 21, same, megaspore mother cell ; Fig. 22, same, megaspore mother cell dividing ; Figs. 23, Dyad dividing ; Fig. 24, linear tetrad of megaspores ; Figs. 25, 26, two embryo sacs in the same nucellus ; Fig. 27, A three nucleate embryo sac, the micropyle nucleus undivided; Figs. 28, 29, four and eight nucleate embryo sacs.

Figs. 19, 21–28 X613 ; Fig. 20 X170 ; Fig. 29 X267.

Acknowledgement :

I am greatly indebted to Prof. B. Tiagi for, suggesting the problem, guidance and keen interest taken by him throughout the progress of work ; also to Dr. G. S. Puri, Director, Central Botanical Laboratory, for interest and encouragement.

References :

Balls, W. L. The sexuality of Cotton. Year book. *Khediv. Agri. Soc.*, Cairo, 1906.

Banerji, I. Development of female gametophyte and floss in *Bombax malabaricum* DC. *Proc. Indian Aca. Sci.*, B. **16** (6) : 205–11, 1942.

Beal, J. M. A study of heterotypic phases in microsporogenesis of cotton. *La Cellule*, **38** : 248–68, 1928.

Davie, J. H. Cytological studies in Malvaceae and allied species. *Jour. Genet.*, **28** : 33–67, 1933.

Denham, H. J. The Cytology of Cotton Plant. Microspore formation of Sea Island Cotton. *Ann. Bot.*, **38** : 407-432, 1924*a*.

——— The Cytology of Cotton Plant. Chromosome numbers in old and new World Cottons. *Ibid.*, **38** : 433–438, 1924*b*.

Eames, A. J. and McDanials, L. H. An Introduction to Plant Anatomy. *New York*, 1947.

Edlin, H. L. A critical revision of certain taxonomic groups of Malvaceae. *New Phyt.*, **34** : 1–20 ; 122–43, 1935.

Gore, U. R. Development of female gametophyte and Embryo in cotton. *Amer. Jour. Bot.*, **19** : 795–807, 1932.

Guignard, M. L. La double fecondation chez les Malvaces. *Jour. Bot.*, **18** : 296–308, 1904.

Gundersen, A. Flower buds and Phylogeny of Dicots. *Bull. Torrey Club.*, **66** : 286–95, 1939.

Maheshwari, P. An Introduction to the embryology of Angiosperms. *New York*, 1950.

Medvedava, G. B. On the embryology of *Hibiscus cannabinus*. *Botanical Zhurnal U. S. S. R.*, **29** (6) : 264–73, 1944.

Metcalfe, C. R. and Chalk, L Anatomy of Dicots. Vol. I. *Oxford.*, 1950.

Puri, V. Placentation in Angiosperms. *Bot. Rev.*, **18** : 693–651, 1952.

Reeves, R. G. Comparative anatomy of seeds of Cottons and other Malvaceous plants. *Amer. Jour. Bot.*, **23** : 291–96 ; 394–405, 1936.

Rao, C. V. Floral Anatomy of some Malvales and its bearing on the affinities of families included in the order. *Jour. Indian Bot. Soc.*, **31** (3) : 171–203, 1952.

Saunders, E. R. Floral Morphology. Vol. I. *Cambridge*, 1937.

Stenar, H. Embryologische studien. *Zur embryogie der Columniferen.* 1–75. *Akad. Abh.* Uppsala, 1925.

Thrimulachar, M. J. and Khan, B. A. Megasporogenesis and Endosperm formation in *Eriodendron anfractuosum*. *Proc. Indian Acad. Sci.* **16**, 1942.

Yamaha, G. Uber die zytokinese bei der Pollentetradenbildung, zugliech weitera Belege Zur Kenntuis der Zyto Kinese im Pflanzenreishe. *Jap. Jour. Bot.*, **3** : 139–162, 1926.

A NOTE ON THE OCCURRENCE OF DHARWAR BRECCIA NEAR MOTIPURA, DISTRICT BARODA, GUJARAT

By

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Department of Geology, Muslim University, Aligarh

[Received on 31st August, 1963]

Introduction :

The Dharwar breccia, under investigation, was recently located by the authors in one of those neglected parts of India where, inspite of its being interesting geologically as well as economically, very little work has been done so far. The breccia was located south of Motipura (22°28′30″ : 73°50′20″), a village lying on the Chota Udepur-Kadwal road. Pani Mines (22°28′50″ : 73°46′40″) is the nearest railway station which is connected by a light railway to Champaner Road (22°33′ ; 73°24′), a railway station on the Ghodra-Baroda chord of Western Railway. An attempt has been made here to describe this hitherto unreported occurrence of breccia. A more detailed account of the same will come out in the form of a Ph.D. thesis which is being undertaken by the junior author.

The breccia, under study, is associated with a group of pre-Cambrian partially metamorphosed rocks of the Panch Mahals and Baroda districts, introduced earlier as the Champaner series by Blanford (1872) who first carried out a geological investigation of this area. Later on, Heron (1917) considered the Champaner series to be analogous to the Delhi system but subsequently, finding no particular lithological similarity between the two, he expressed that the Champners might be continuous with the Aravalli series of Rajputana, (Heron 1934). Fermor (1934), while studying the nomenclature of the ancient schistose rock series of India, considered the Champaners, the Aravallies, the Chilpi Ghat series and the Dharwars of Mysore to be roughly homotaxial. He also observed that the Champaner series might be a component of the Dharwar system, and accordingly stressed that the metamorphic rocks of the region should be known as the Dharwar system instead of the Champaner series.

In the past, parts of Panch Mahals and Baroda districts had recieved some attention of Hobson who surveyed an area of about 152 square miles in the then Chota Udepur State (22°20′ : 73°49′) and prepared a geological map (1926, plate 24). The rock types, described by him, include only quartzites, limestones, calc-granulities, phyllites, slates and schists belonging to the Champaner series and also a suit of granite intrusive into the schistose series.

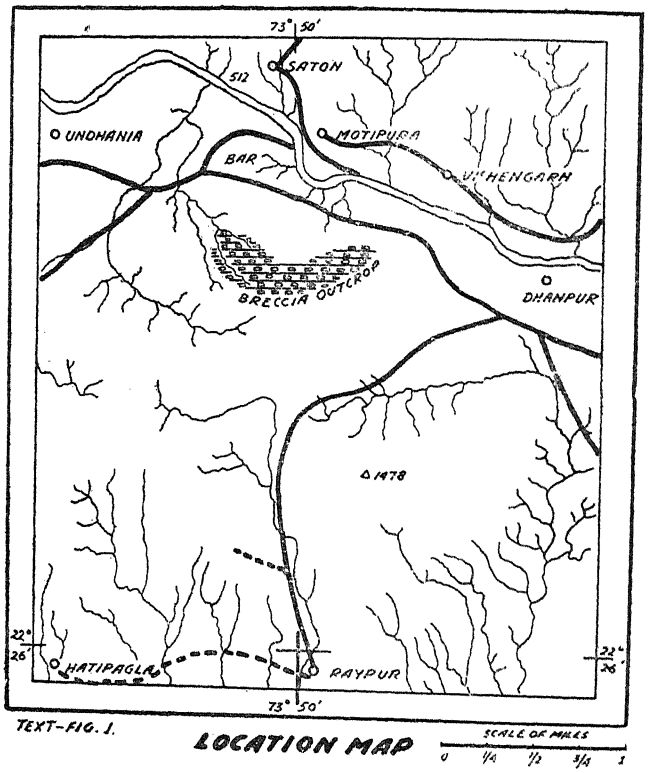
Gupta and Mukerjee (1938), while compiling a regional geological map of the southern Rajputana and Gujarat (between latitudes 22° and 24° ; and longitudes 73° and 74°45′) on the basis of earlier surveys done by the previous G. S. I. officers, did not refer anything about the occurrence of breccia described below.

Field and lihtological characters :

The breccia appears to be overlying the phyllites conformably, which is largely restricted to the north of the former ; and a massive quartzite, occurring

below the phyllites, is conspicuously exposed in the form of a steep ridge striking parallel to the breccia on the south.

The breccia strikes roughly in an east-west direction (Text Fig. 1) and it may be seen outcroping almost continuously for about a mile along a small ridge just south of Motipura. The eastern end of the ridge is about a mile south-west of Vishengarh (22°28′20″ : 73°50′45″), and its western end is about a mile of south-east of Undhania (22°28′30″ : 73°40′45″).



TEXT-FIG. 1.

The strike of the breccia varies from N 75 E to N 80 W and due to its highly disturbed nature, dips vary to a certain extent from place to place. However, generally the dip is highly inclined and varies from 85 N to 85 S and at a number of places, it was found to be nearly vertical. Occasionally, the matrix of breccia preserved some of their original sedimentary features such as graded and cross beddings. Some drag folds have also been noticed in the matrix.

The breccia, being a very resistent rock, crops out prominently throughout its extension in the field. It is very hard and breaks with much difficuly. It looks greenish-grey in colour from a distance. In hand specimen the angular nature of the bigger fragments is quite distinct and the fragments of pink quartzite, dark biotite-granulite and calc-actinolite schist may easily be identified. Some of these fragments measure upto 2–3 inches in length and most of them, although retaining their angular outlines, are somewhat elongated in the direction of schistosity of the groundmass. There is also no difficulty in identifying the smaller

fragments of quartz, felspars, actinolite, tourmaline and magnetite in the groundmass using a magnifying lens.

Petrographic characters :

The breccia is heterogenous in composition and the coarser fragments have some disparity in their shape and size. Most of the fragments are angular and enclosed in a fine-grained schistose matrix composed largely of sericitic material. The predominant fragments are essentially detrital and they include quartz and quartzites, biotite granulite, felspar, tourmaline and zircon, The fragments of quartz show wavy extinction and in most cases their outlines are serrated.

Often the quartz and quartzites fragments are fractured showing evidence of cataclastic effect. The felspars, which occur in a subordinate amount, include orthoclase, microcline and a little of plagioclase. Almost all of them turned more or less turbid due to partial alteration into scricite or kaolin. There are some fragments of fine-grained biotite-granulite showing practically no change in their original composition. Fragments of tourmaline occur in the breccia but less frequently than those described earlier. Most of them are fractured closely and the fractures are filled with quartz. Zircon is rare and occurs in small rounded fragments. The minerals of metamorphic origin may be magnetite, actinolite, biotite, chlorite, muscovite and sphene. Calcite is also associated with the rock but in a very little quantity. Among these minerals, actinolite is the most predominant and occurs in clusters imparting a greenish appearance to the rock. Biotite and muscovite occur in small flakes distributed throughout the matrix. Euhedral to sub-hedral crystals of magnetite are fairly common.

Conclusion :

By virtue of its cross-bedded and graded nature of the matrix, the polygenetic breccia, having angular fragments of quartz, quartzite, calc-actinolite schist, biotite-granulite, tourmaline, etc., may be considered to be of sedimentary origin. The schistose nature of the matrix and the presence of recrystallised minerals such as, actinolite, biotite, chlorite, muscovite, etc., indicate that the breccia had undergone some amount of metamorphism since compacted and the grade of metamorphism does not seem to exceed that of Barrow's Biotite Zone. [*see* Harker, 1950].

Summary :

This paper includes some field and petrographic accounts of a hitherto unreported occurrence of Dharwar breccia, recently located by the authors south of Motipura (22°28°3′0″ : 73°50′20″), district Baroda, Gujarat.

The breccia forms a small ridge which extends in an east-west direction for about a mile in the area under investigation. It is composed largely of angular fragments of fine-grained quartzite, calc-actinolite schist, quartz, biotite-granulite, and all of them are embedded in a fine-grained groundmass of quartz, biotite, actinolite, muscovite and sericite. The matrix is somewhat rendered schistose and occasionally shows primary sedimentary features such as. cross and graded beddings. Most of the larger fragments are also stretched parallel to the general schistosity of the groundmass.

Based largely on its mode of occurrence, heterogenous composition and petrographic characters, the breccia, which had also undergone some degree of metamorphism since compacted, is considered to be epiclastic.

References :

Blanford, W. T. Sketch of the Geology of the Bombay Presidency. *Rec. Geol. Surv. Ind.* **V** : 85, 1872.

Fermor, L. L. General Report for 1933. *Rec. Geol. Surv. Ind.*, **LXVIII** : 25, 1934.

Gupta, B. C. and Mukerjee, P. N. The Geology of Gujarat and Southern Rajputana. *Rec. Geol. Surv. Ind.*, **LXXIII** : 163-204, 1938.

Harker Alferd. Metamorphism—A study of the transformation of rock masses. p. 209, 3rd Edn., Methuen & Co., Ltd., London. 1950.

Heinrich, E. Wm. Microscopic Petrography. McGraw-Hill Book Company, Inc., N. Y., 1956.

Heron. A. M. Geology of northern-eastern Rajputana and adjacent districts. *Mem. Geol. Surv. Ind.*, **XLV** : 25, 1917.

——— General Report for 1933. *Rec. Geol. Surv Ind.*, **LXVIII** : 6, 1934.

Hobson, G. V. The metamorphic rocks and intrusive granite of Chhota Udepur State. *Rec. Geol. Surv. Ind.*, **LIX**, 340–356, 1926.

Rogers, A. F. and Kerr, P. F. Optical Mineralogy. McGraw-Hill Book Company, Inc., N. Y., 1942

Williams, H., Turner, F. J. and Gilbert, C. M. Petrography—An introduction to the study of rock in thin sections. W. H. Freeman and Company San Francisco, 1955.

EXPERIMENTAL FISHING AT THE METTUR DAM, CAUVERY RIVER*

By

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[Received on 4th February, 1963]

Introduction :

Mettur Dam reservoir is constructed across the river Cauvery at a distance of 56 Km. from Salem town (Fig. 1). The Dam is 37·6 metres high and impounds 95,660 m.cft. of water. Above the dam on the left side is surplusing channel called Ellis surplus which joins the river down stream. The reservoir is used for irrigation and hydroelectric generation and fisheries. The river bed and the surrounding area is extremely rocky. The upper limit of the reservoir is near Hoganikal falls which hampers the free migration of fish upstream and thus the reservoir is a self contained unit as far as fisheries is concerned. Due to these natural barriers, at Hoganikal and further upstream at Shivasamudram, the fish fauna in Mettur reservoir and Krishnaraj Sagar reservoir is different.

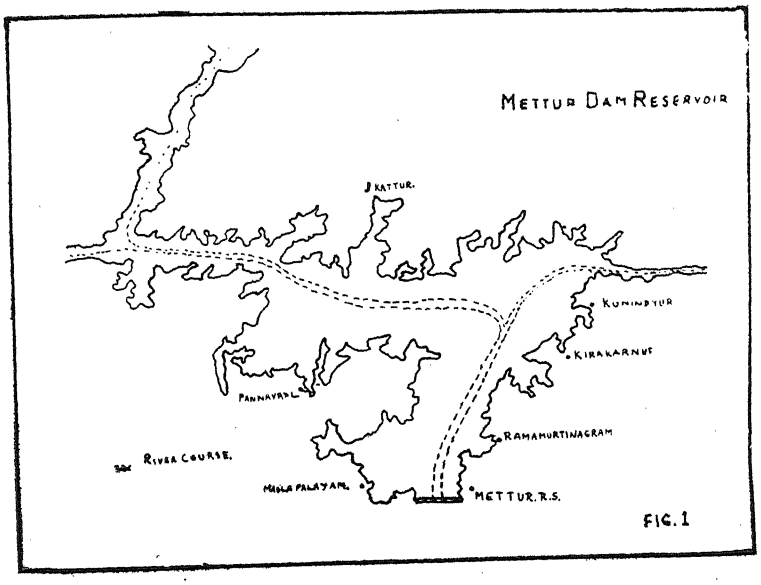

Fig. 1. Out line map of Mettur Dam

The dam was completed in 1934, and since then stocking was started. Raj (1941) gave an account of the effect of the dam on the fisheries of the river in general.

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First the Fisheries Department of Madras State carried out experimental fishing with gill nets. Various modifications of these nets were used. During 1949–1950 departmental fishing units and 94 licencees caught 12·68 m.tons of fish.

Since 1950 Rangoon nets are being used continuously along with Uduvala nets.

At present the department issues liscences to fishermen for fishing in the reservoir. All the fish caught is marketed through the Fishermen Co-operative Society who maintain detailed records of catch per man and catch of various species. The fishery of this reservoir is the best organised one in India and ha served as a model for fisheries development work in other reservoirs.

The deep water fishing expert from F. A. O. selected this reservoir for experimental fishing work with gill nets and during April, May and first week of June, 1960. Fishing with gill nets was carried out under the guidance of the expert, the results of which are given here. The details of the gear used is given in the report of the expert (Gulbadamov, 1962).

Limnological observations :

During the present work data on surface water temperature, transparency and dissolved oxygen were callected. Besides this some previous data are available from the report of Menon, Srinivasan and Krishnamurty (1959). The data on water level of the reservoir are collected by the office of the Executive Enginner, P. W. D , Mettur Dam. The Fisheries Department also collects data on surface water temperature. These data on water level and surface water temperature were made available to the expert.

The water level reaches its minimum in May—June. During July—September the water level rises and reaches the maximum depending upon floods. Then there is a slight decrease during October—January or February. During March—April there is a marked decrease reaching minimum in May—June.

The surface water temperature is maximum during April—May (26·7–31·4°C) and minimum in December—January (23·2—25·9°C).

In June, 1947 (Menon, Srinivasan and Krishnamurty, 1959), the difference between surface and bottom temperatures was 2·7°C. Free Carbon Dioxide at deeper layers was 2·09–2·75 p.p.m. Corbonates were present in surface water only (19·5 p.p.m.). pH at surface was 8·5 and at 94 ft. (28·65 m) was 7·6. Dissolved oxygen at surface was 4·26 cc/l. and at 44-ft. (13·41 m) depth was completely absent and at this depth Hydrogen sulphide was found (1248 mg/l.). Phosphates were 0·03–0·05 p.p.m.

This showed that during summer there is stratification and consequent stagnation of water at deeper layers.

During November, 1947, the entire column of water was found to be well oxygenated. In February, 1948, thermal stratification was noticed at depth of 51 ft. (15·54 m).

During April—May, 1960, the surface water temperature was 27·2–33°C., transparency by Sechi disc was 60–115 cms. and disolved oxygen in surface waters was 7·0–9·6 mg/l.

In the phytoplankton Blue green predominated and in Zooplankton Rofifera were more.

Fish fauna and fisheries :

Chacko, Kuriyan and Thyagrajan (1955) have surveyed the river Cauvery and have given information about its limnology and fauna. They have recorded 80 species of fish, of which 42 species belong to Cyprinidae and 14 species belong to Siluridae. According to them *Catla catla* (475 fingerlings) was first introduced in the river in the pool at Hoganikal in 1923. *Cirrhina mrigala* another Indo-Gangetic carp was introduced later on. Both these species are now well established in the river and contribute substantially to the fisheries of the reservoir. Sixty six per-cent of thc Inland fishery reveaue of the State is reported to be obtained from this river. The fish seed resources of this river are reported to be maximum compared to Krishna, Godavari and Tungabhadra rivers (Menon *et al* 1959).

The figures for total catch and number of liscences issued and departmental fishing units operating in the Mettur reservoir were kindly supplied by the Assistant Director of Fisheries, Mettur Dam (Table I) for the years 1951-52 to 1959-60 (except for the year 1955-56). The annual catch per unit varied between 0·478 m. tons (1956-57) to 2·734 m. tons (1958-59). The average catch per unit for the eight years is 1·52 m. tons. It is presumed that a man fishes for 250 days in a year. On this basis the daily eatch per man for the eight years is 1·91 Kg. to 10·94 Kg. (average 6·05 Kg.).

TABLE I

Total Catch, number of liscences, catch per unit per year and per day for Mettur Dum Reservoir for years 1951-55 and 1956-60.

Year	No. of liscences and departmental Units	Total catch (Metric tons)	Annual catch/ unit (M. tons)	Daily catch/ Unit (Kg)
1951-52	246	628·80	2·556	10·220
1952-53	193	423·40	2·193	8·772
1953-54	218	192·83	0·884	3·536
1954-55	121	183·31	1·514	6·056
1956-57	217	103·70	0·478	1·912
1957-58	246	285·19	1·159	4·363
1958-59	193	527·76	2·734	10·936
1959-60	249	163·21	0·655	2·620
Average			1·521	6·051

It is seen that there are wide fluctuations in the catch per unit from year to year, but no plausible reason for these can be given at present as the data on various factors, meteorological, limnological and biological are not available at present.

The fishing is mainly confined to four places in the reservoir. They are Paunavadi, Kirakarnur, Konindyur and Maslapalyam (Text fig. 1). The data on total catch and the number of persons fishing at these four centres were supplied by the Fishermen's Co-operative Society for the year 1959 and January—May, 1960. The data for the year 1959 were examined (Table II) and catch per man per day

at these four centres and average catch per man per month for all the four centres were calculated. The seasonal fluctuations showed that maximum catch was obtained in the month of June (17·36 Kg.) and minimum in December (4·62 Kg.). During February to July the catches are above the average (9·48 Kg.) and during January and August—December the catches are poor. The catch per man per day at Maslapalyam varied between 4·00 Kg.–17·10 Kg. (average 8·44), for Kirakarnur 3·46 Kg.–20·6 Kg. (average 8·66 Kg.), for Konindyur 5·35 Kg.–16·33 Kg. (average 10·31 Kg.) and for Pannavadi 5·67–18·27 Kg. (average 10·53 Kg.) showing that fishing at Pannavadi and Konindyur are better than at Maslapalyam and Kirakarnur. On an average a man uses 20 nets (both Rangoon nets and Catla nets) and so the catch per net is 0·474 Kg. This is compared with the catches in experimental nets.

TABLE II

Catch per man per day (in Kg.) at four fishing centres at Mettur Reservoir in 1559

Month	Maslapalyam	Kirakarnur	Konindyur	Pannavadi	Average
January	5·17	7·38	9·45	8·64	7·66
February	10·26	7·78	13·54	9·40	10·24
March	9·18	7·65	9·94	9·67	9·11
April	9·90	10·03	13·81	13·95	11·92
May	13·23	12·60	11·07	18·27	13·79
June	17·10	20·61	16·33	15·43	17·36
July	11·52	10·03	12·01	13·63	11·79
August	3·96	6·30	9·18	8·59	7·00
September	5·76	7·42	7·06	8·55	7·19
October	6·21	6·25	9·00	8·28	7·43
November	5·04	4·45	7·06	6·34	5·72
December	4·00	3·46	5·35	5·67	4·62
Average	8·44	8·66	10·31	10·53	9·48

Experimental fishing :

Was done for 62 days, 27 days in April, 31 days in May and 4 days in June, 1960. Monofilament nets and surface gill nets made of Terelyne twine having a mesh of 2″, 2·5″, 3″, 3·5″, and 4″ were used. Two trammel nets (2″ mesh) were also used. In 3″ net one net was with sinkers and another net was without sinkers.

The nets were laid near the dam, and at Kirakarnur and Pannavadi. The results are detailed below.

Fishing with monofilament nets :

Nets made of monofilament twine 77·3 metre long and 1·5 metre in depth were used near the margin. 8–10 nets were laid per day. Fishing with these nets was done for 54 days using a total of 483 nets. The total catch was 643·8 Kg.

giving catch per net as 1·33 Kg. In all 22 species of fish were caught in them *Cirrhina reba* was the predominant species forming 45·77% of the catch. Carps formed 78·79% of the catch, siluridae formed 12·65% of the catch and the rest was contributed by other miscellaneous species. In Table V the total number and weight, and number of days the species was caught is given. Length range and mean length for 10 species is also given. In these nets only the uneconomical varieties were caught which normally would compete with the ecconomically important species for food. Only eight species are caught in Rangoon nets. This also shows that generally the larger fishes live away from the shore in the deeper parts. The catch per net per day in these nets is slightly higher than that at Krishnaraj Sagar (1·29 Kg.).

Fishing with Rangoon nets :

The total number and weight of different species obtained in various nets were recorded. In Table III data on 3″ nets with sinkers and without sinkers are given separately but for fish species these are combined (Table IV). The catch per net day showed that minimum catch was obtained in 2·5″ meshed net, followed by 2″, 3″ (without sinkers), 3·5″, 4″ and trammel net. The net with sinkers gave the minimum catch. The catch in 3″ net without sinkers was 8·5 times the catch in net with sinkers. This shows that sinkers appreciably effect the catching capacity of the nets. The reason may be that due to the weight of the sinkers the net is taut and not free at the lower end. The fish when it comes in contact with the net easily gets away. In cases where there are no sinkers the net is free and when the fish comes in contact with the net, even if not properly gilled, tries to get away, but in doing so it gets entangled in some mesh. Because the fishes are active and heavy merely gilling does not retain them in the net but in addition they are entangled also.

TABLE III

Number of net days, total catch by number and weight, weight per lift and weight per fish in different nets

	2″	2·5″	3″ (Sinkers)	3″ (No sinkers)	3·5″	4″	Trammel net	Total
No. net days	73	23	76	77	33	28	95	405
Total No. fish	293	62	14	87	28	5	40	529
Total weight (Kg.)	223·53	75·92	18·52	159·94	44·65	19·89	37·64	580·09
Weight/Lift (Kg.)	3·062	3·300	0·244	2·077	1·353	0·674	0·396	11·106
Weight/Fish	0·763	1·224	1·323	1·838	1·594	3·978	0·941	11·661

The total catch in seven nets per day is 11·106 Kg. Since the price of fish at Mettur is 30 nP. per lb. the income a fishermen will earn is Rs. 7·40 nP.

As stated in the previous section average daily catch per man using 20 nets was 9·48 Kg. giving him an income of Rs. 6·42 nP. during 1959.

This shows that catch in the experimental nets is much better. This is further examined in greater detail in another section.

TABLE IV

Number and weight (Kg.) of species in different nets

Mesh	2″		2·5″		3″		3·5″		4″		Trammel net		Total		% Weight
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt	No.	Wt.	No.	Wt	No.	Wt.	
C. Cirrhosa	51	69·32	36	51·11	44	75·22	15	25·71	2	4·36	10	12·77	158	238·49	41·12
C. reba	23	15·00	–	–	2	1·02	–	–	–	–	1	0·81	26	16·83	2·90
C. mrigala	5	11·74	1	1·91	11	51·08	5	13·30	3	15·53	1	0·95	26	94·51	16·29
L. kontius	1	0·38	3	2·15	–	–	–	–	–	–	–	–	4	2·53	0·44
L. calbasu	2	0·83	–	–	–	–	–	–	–	–	–	–	2	0·83	0·14
B. dubius	2	0·95	2	1·05	1	0·62	–	–	–	–	2	1·40	7	4·02	0·69
M. seenghala	3	2·76	–	–	3	10·38	–	–	–	–	2	4·79	8	17·93	3·09
M. aor	30	13·61	2	0·17	6	5·04	–	–	–	–	4	2·52	42	21·34	3·68
P. pangasius	52	37·53	8	11·53	8	7·60	1	0·73	–	–	2	0·59	71	57·98	9·99
S. silondia	123	68·18	10	8·00	25	24·15	7	4·91	–	–	17	12·78	182	118·02	20·35
W. attu	1	3·23	–	–	1	3·35	–	–	–	–	1	1·03	3	7 61	1·31
	293	223·53	62	75·92	101	178·46	28	44·65	5	19·89	40	37·64	529	580·09	100

The experimental nets wers laid near the dam, at Pannavadi and at Kirakarnur. The catch per net per day at these places was calculated to find the fishing success at different places in the reservoir. It was seen that the catch per net day near the Dam and at Pannavadi and Kirakarnur was 0·56 Kg., 1·19 Kg. and 2·25 Kg. showing that catches near the dam are poor. In the catches of the local fishermen also the catch at Maslapalyam which is near the dam are least.

TABLE V

Catch in monofilament nets

Species	No. days caught	Total number	Total weight (Kg.)	Length range (mm.)	Average length
Barbus dorsalis	54	1,077	61·72	121–210	166·2
B. sarana	45	246	36·34	181–300	236·9
B. mahecola	34	535	19·75	–	–
B. carnaticus	3	28	4·63	–	–
B. dubius	17	50	11·68	–	–
Cirrhina reba	54	4,181	294·72	170–310	225·0
C. cirrhosa	13	16	5·71	–	–
Labeo kontius	27	170	21·20	151–380	278·5
Labeo sp.	43	388	32·23	161–240	200·1
L. fimbriatus	1	6	0·68	–	–
L. calbasu	41	123	18·09	151–330	230·0
Chela sp.	7	11	0·51	–	–
Mystus aor	45	163	30·99	161–440	337·5
M. seenghala	7	64	8·61	–	–
S. silondia	48	314	28·07	161–370	245·8
P. pangasius	10	11	3·20	–	–
Callichrous sp.	34	114	7·08	–	–
M. cavasius	24	79	3·95	161–240	203·8
N. notopterus	55	527	52·39	181–300	251·7
Mastacembelus sp.	10	13	2·07	–	–
G. giuris	4	4	0·31	–	–
Etroplus suratensis	3	4	0·32	–	–
Total ...		8,242	643·8		

Relative abundace of species :

In all 14 species of fish were caught in the nets. Of these 6 species *i.e.*, *C. cirrhosa*, *C. mrigala*, *S. silondia*, *P. pangasius*, *M. aor* and *M. seenghala* contributed 94·52% of the catches. In 2″ net *S. silondia* and *C. cirrhosa* were caught much more than other species. In 2·5″ net *C. cirrhosa* formed nearly 75% of the catches. In 3″ net (both with and without sinkers) *C. cirrhosa* and *C. mrigala* predominated followed

by *S. silondia*. In 3·5″ net also the catch of species was same as in 3″ net In trammel net (mesh 2″) the catch was more or less similar to that of 2 Rangoon net except that *L. kontius* and *L. calbasu* were not caught in trammel nets Thus it may be concluded that in nets having a mesh of 2″, 2·5″ and 3″ most o the species are caught and in 3·5″ and 4″ nets only 2–4 species are caught.

Details of species :

C. cirrhosa.—This species contributed 41·12% by weight of the total catch The length range and mean was 368–610 mm. and 509 mm. respectively. Th mean length, head and body girth of the specimens caught in various sized nets i given below. Due to the number of specimens being few no clear cut relation ship between the length and mesh is seen.

Mesh	2″	2·5″	3″	3·5″	4″	Tr.
Tl.	499	498	534	512	525	501
Head girth	211	213	236	224	230	222
Body girth	295	307	324	336	325	304

The length weight relationship is given by the following equation.

$$\text{Log } W = -4{\cdot}84033 + 2{\cdot}9745 \text{ Log } L.$$

TABLE VI

Observed and calculated length at age of *C. cirrhosa*

Age	*Observed* Length (m)	Growth	*Calculated* Length	Growth
1	200		198	
		72		73
2	272		271	
		67		65
3	339		336	
		57		58
4	396		394	
		53		52
5	449		446	
		47		47
6	496		443	
		44		42
7	540		535	

The age and growth studies were done from the scales studies. Scales from 103 specimens were examined. As in case of *B. carnaticus* and *B. dubius* (Tripathi—manuscript) the relationship between the growth of the scale and body is assumed to be linear and it is presumed that only one ring is formed in a year. On this basis the length attained at various ages are given in Table VI and the various rates of growths in length and weight are also calculated. (Table VII). It is found that while the rate of monthly growth in length decreases, but the monthly rate of growth in weight increases. (figs 2 and 3).

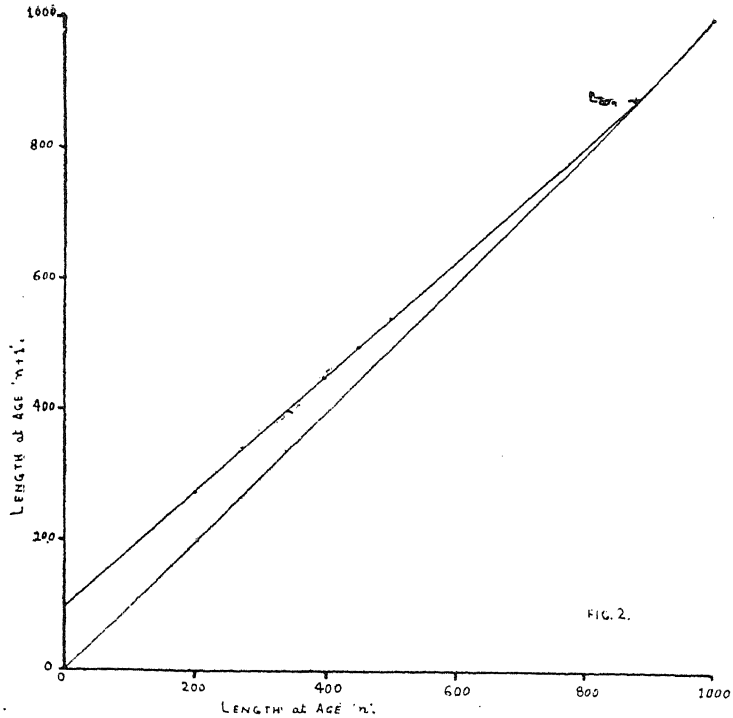

Fig. 2. Wafford graph for *C. cirrhosa* Length at age '*n*' plotted against age $n+1$.

Van Bertalanffy's growth equation was fitted to the growth in length data and by drawing Walford graph l_{oo} and e^k was found. By plotting log $(l_{oo}-l_t)$ against age, t_o was calculated. The values of l_{oo} t_o and k were found to be 887 mm.-1·25 and 0·1120 and the equation is :

$$l_t = 887\ (l-e^{-0.112})\ (l+1{\cdot}25)$$

TABLE VII

Growth rates in length and weight of *Cirrhina cirrhosa*

Age	Length	Growth	Growth/ month	Weight	Growth	Growth/ month	Annual growth rate (h)	Instantaneous growth rate (i)
1	200	200	16·60	101	101	8·3	–	–
2	272	72	6·00	252	151	12·59	1·49	0·9118
3	339	67	5·58	485	233	19·41	0·92	0·6523
4	396	57	4·75	770	285	23·75	0·58	0·4573
5	449	53	4·41	1119	349	29·08	0·45	0·3716
6	496	47	3·92	1504	385	32·08	0·34	0·2926
7	540	44	3·66	1937	433	36·08	0·28	0·2468

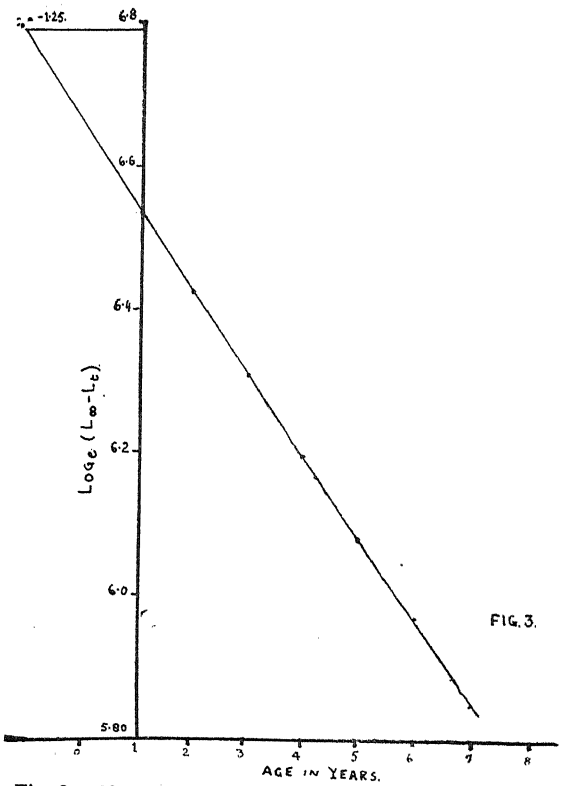

Fig. 3. Plot of log e (l_{oo}-l_t) against age for *C. cirrhosa*.

The calculated lengthens (Table VI) are not appreciably different from the observed lengths. But these claculations are only tentative as further proof of growth at earlier stages is required. The percentage age composition of the catch was as follows :

Age	3	4	5	6	7
%	6·79	20·39	35·92	26·22	10·68

This shows that ages 4–6 predominate in the catches.

C. reba.—This species formed only 2·9% of the total catch and was mainly caught in 2″ net. The size range was 358–404 mm. and mean was 338·8 mm. This species predominated in monofilament nets.

C. mrigala.—Only 26 specimens were caught but by weight they formed 16·29% of the total catch. It was mainly caught in 2″, 3″ and 3·5″ meshed nets. The mean length (in mm.) for various mesh sizes was as follows :

2″—556, 2·5″—441, 3″—696, 3·5″—576, 4″—754 and trammel net 430, showing that like *C. cirrhosa* in this case also there is no relation between the mesh size and the mean length of the fish. This is mainly due to the sample being very small.

Only a few specimens of *L. kontius*, *L. calbasu*, *B. dubius*, *M. seenghala* and *W. attu* were obtained and so they are not being dealt with here.

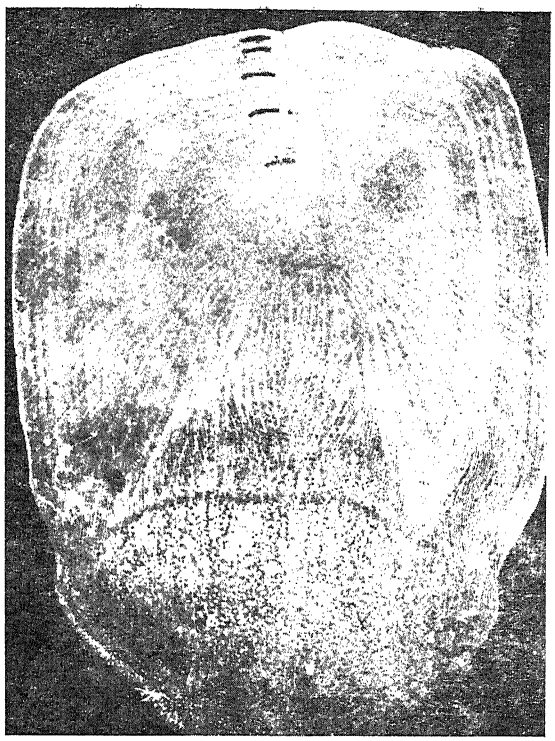

Fig. 4. Photograph of scale of *C. cirrhosa* 442 mm long showing five rings.

M. aor.—42 specimens of this fish were caught and by weight formed 3·68% of the total catch. Majority of the specimens were caught in 2″ net only. The mean length of fish caught in different nets is as follows : 2″—446 mm. 2·5″—454 mm., 3″—417 mm., trammel nets 471 mm.

Pangasius pangasius.—This species formed nearly 10% of the catches and was mainly caught in 2″ net The size range varied between 286 mm.—610 mm. and mean length was 442 mm. The mean length in 2″ net was 447 mm., in 2·5″ net 533 mm. and in 3″ net 469 mm. This fish gets deteriorated very soon during summer and quite often rotten specimens were colleted from the net. Same is the case with *S. silondia* also.

S. silondia.—Like *P. pangasius* this species was also mainly caught in 2″ net only. It formed 20·35% of the total catch. The length range was 233—665 mm. with a mean of 419 mm. The mean length in different meshed nets was 2″—389 mm. 2·5″—416 mm., 3″—463 mm., 3·5″—508 mm. and Trammel net 426 mm.

Remarks :

The experimental fishing with gill nets showed that the catch with 7 nets was 11·106 Kg. per day. The catch by local fishermen per day for April and May, 1960 was calculated to be 8·27 Kg. The average for the year 1959 was 9·49 Kg. per day. This catch is obtained in nearly 20 nets. The length of the net of local fishermen is 37·6 to 40 metres, so the total length of net that a man uses in

one day is nearly 752–800 metres. The height of the net is 4·45 metres. The total area of the net is nearly 3346–3560 sq. metres. The total area of the experimental nets was 2245·5 sq. metres.

	Total area of net (sq.m).	Catch (Kg)	Catch/1000 sq.m.	Ratio
Local net	3453	8·27	2·392	1
Experimental net	2245	11·106	4·947	2·06

This show that the catch by the experimental nets is nearly double that of the local nets and this is definitely a great improvement because at once the income of the fishermen is doubled for the same effort.

The reservoir maintains a profitable fishery and with the introduction of the improved nets as suggested by Gulbadamov (1962) the catch will further improve.

In the section on limnology it was seen that during summer thermal stratification takes place and that sulphurated hydrogen is produced at the bottom at a depth of 44 ft. This will cause some mortality of fish during the turn over when the floods come in. But the concentration will be reduced to a great extent. Further detailed work on this aspect is necessary.

Summary :

Data on fish catches by local fishermen and by experiment gill nets were analysed and compared. There are great fluctuations in catch per unit from year to year. Of four places where fishing is concentrated Konindyur gives highest catch followed by Pannavadi, Kirakarnur and Maslapalyam. The average daily catch per man at these 4 centres during 1959 was 9·48 Kg. Monthly variation in catches shows that the maximum catch per unit is in June and minimum in December.

In experimental fishing highest catch was obtained in 2·5″ nets. In three inch meshed net with sinkers the catches were 8·5 times less than in a net of similar mesh and size but without sinkers.

The catch per unit area in experimental nets is double that of the local fishermen's nets.

Cirrhina cirrhosa, *C. mrigala*, *S. silondia* and *P. pangasius* contributed to the catches mainly. The growth rate of *C. cirrhosa* has been calculated.

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References :

Van Bertalanffy, L. A quantitive theory of organic growth to *Human Biology.* **10** (2) : 181—213, 1938.

Beverton, R. J. H. and Holt, S. J. On the dynamics of exploited fish populations. *U. K. Min. Agr. and Fish. Invest* Ser 2 **19** : 533 pp., 1957.

Bhimachar, B. S. Report on the survey of fisheries of Mysore State Bull. Dept. Agric. Mysore **1** : 1–39, 1942.

Carlander, K. D. Some considerations in the use of growth data derived from scale studies. *Trans. Amer. Fish Soc.* **79** : 187–194, 1950.

Chacko. P. I. and Krishnamurthy, B. Age and growth of Carp *Labeo fimbriatus* as revealed by scales. *Indo-Pacific Fisheries Council* (Technical paper 29 Summary), 1951.

Chacko, P. I. and Srinivasan, R. Hydrobiology of the major rivers of Madras State, South India. *Contrib. Fresh water. Fish Biol. Stn.* No. 13, 1955.

Gulbadamov, S. B. Improvement of fishing techniques in Inland Reservoirs Report to Government of India, E. T. A. P/F. A. O. Report No. 1499 : 37 pp, 1962.

Hile, Ralph. Age and growth of cisco *Leucichtys artedii* (le sueur) in the lakes of the Northeastern Wiscousin. *Bull. U. S. Bur. Fish.* (19) : 211–317, 1936.

Jhingran, V. G. Studies on the age and growth of *Cirrhina mrigala* (Ham) from the river Ganga. *Proc. Nat. Inst. Sec. India,* **25** (B) : 107–137, 1959.

Menon, M. D. The determination of age and growth of fishes of tropical and sub-tropical waters. *J. Bombay Nat. Hist. Soc.* **51** (3) : 623-635, 1953.

Menon, M. D. Srinivasan, K. and Krishnamurthy, B., Report to the Indian Council of Agricultural Research on the Madras rural pisiculture scheme worked from 1st July, 1942—31st March 1952. Govt. of India Press. Madras, 171 pp. 7 1957.

Ricker, W. E. Hand-book of computations for biological statistics of fish populations. *Fisheries Res. Bd. Cannda.* Bulletin No. 119 : 300 pp. 1959.

Rounsfell, G. A. and Everhart, W. H. Fishery sciences its methods and applications. *John Wiley, & Sons,* 444 pp., 1953.

Van Brandt, A. The efficiency of drift nets. *J. du Consiel,* **21** : 9–16, 1955.

Van Oosten, J. Life history of the lake Herring (*Leucichthys artedii* Le Sueur) of Lake Haron as revealed by its scale with a critique of the scale method. *Bull. U. S. Bur. Fish,* **44** : 265–448, 1929.

Walford, L. A. A new graphic method for discribing the growth of animals, *Biol. Bull.* **90** (2) : 141–147, 1946.

THE BOTANY OF COORG FORESTS II*

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In an earlier paper in this Journal (Arora, 1960), the general information regarding the location, geology, soil and climate, and the floristic composition of the forest types for the district of Coorg (11°56′ – 12°50′ N and 75°22′ – 76°12′ E) was presented. These studies were followed by a detailed analysis of the forest communities with emphasis on their interrelationship and successional trends (Arora, 1964). In continuation of this work, a further contribution dealing with the flora of the area is presented in this paper. The following aspects are covered:

(1) The flora of the lowlands.

(2) The flora of the uplands.

(3) The monsoon flora.

(4) The aquatic vegetation.

(5) The riverain vegetation.

(6) The flora of the waste grounds and rice fields.

(7) The economic aspect of the flora.

(8) Phytogeographical notes.

(9) Enumeration of the species collected.

As has already been pointed out in the earlier paper (Arora, 1960) this mountainous district with a range of irregular hills can be divided into two parts—the uplands and the lowlands. The lowlands chiefly lie in the eastern and northern side and support a deciduous vegetation, while the uplands are located mainly in the central, southern and western parts, are densely wooded and support an evergreen vegetation which presents the climatic climax for the area. The flora of the lowlands due to the influence of the climatic and edaphic factors differs remarkably from that of the uplands (which get more of rainfall) as is discussed below.

1. The flora of the lowlands :

The lowlands cover the eastern and northern belt of the district and the flora prevailing here is either a mixture of hardy or thorny shrubby components composing a scrub forest, or a dry/moist deciduous forest depending upon the intensity of rainfall, temperature, soil and biota. The scrub type prevails near Hunsur and is composed of species like *Carissa congesta*, *Capparis* spp., *Balanites aegyptiaca*, *Ixora arborea*, *Randia dumatorum*, *Acacia* spp., *Flacourtia indica*, *Fluggea* sp., *Gymnosporia montana* etc. The dry deciduous type has however a better growth of species like *Pterocarpus marsupium*, *Diospyros melanoxylon*, *Buchanania lanzan*, *Bauhinia racemosa*, *Santalum album*, *Bridelia squamosa*, etc. and has less of thorny components,

*Material taken from Ph.D. thesis of the author approved by Punjab University.

while the moist deciduous type in Kalhalla, Tittimatti and Nagarhole, includes *Bambusa bambos*, *Dendrocalamus strictus*, *Emblica officinalis*, *Dillenia pentagyna*, *Grewia tiliaefolia*, *Lagerstroemia lanceolata*, *Tectona grandis*, *Terminalia tomentosa* etc. The details of the floristic composition of these forests have already been described (Arora, *loc. cit.*) The flora in these lowlands is also composed of drier-habitat plants like *Blepharis boerhaaviaefoliva*, *Aerva monsoniae*, *Ehretia buxifolia*, and *Rhus mysorensis*.

2. The flora of the uplands.

The uplands of the district are distributed over the long belt of Subramanyam range which lies on the Western ghats. The rainfall here is high (at many places over 500 cm. per annum) and is accompanied by high humidity and temperature thus creating favourable climate for the growth of tropical evergreen flora. The foot of the uplands invariably support a mixture of evergreen and semievergreen components like *Acrocarpus fraxinifolius*, *Albizzia chinensis*, *Xylia xylocarpa*, *Bischofia javanica*, *Tetramales nudiflora*, *Zanthoxylum rhetsa*, *Strychnos nux-vomica*, *Litsaea* spp., *Garcinia* spp., *Holigarna* sp., *Olea dioica*, *Cinnamomum zeylanicum* etc. while the rain forest proper in these uplands is composed mainly of evergreen species like *Vateria indica*, *Pithecolobium bigeminum*, *Calophyllum* spp., *Artocarpus hirsuta*, *Actinodaphne* sp., *Holigarna grahamii*, *Hardwickia pinnata*, *Knema attenuata*, *Euphoria longana*, *Nephelium stipulaceum* etc. The orchid flora is rich and many species of *Oberonia*, *Aerides*, *Dendrobium*, *Bulbophyllum neilgherrense*, *Pholidota imbricata* etc. are met with.

3. The monsoon flora.

The monsoon aspect has not been studied to a greater detail since it is very difficult to undertake exploration work all along during this period. The monsoon type differs from others as during this period many short lived plants make their appearance and many others especially the suffruticose and herbaceous climbers generally with bulbous and rhizomatous underground portions, start producing green shoots. Thus species of *Dicosorea*, *Asparagus*, *Smilax*, *Ipomoea*, and many others from Liliaceae, Amaryllidaceae, Scitamineae, come up during this time. *Arisaema* spp., *Curcuma* spp., *Scilla* spp., *Curculago orchioides*, with herbs like *Biophytum sensitivum*, *Cleome viscosa*, *Smithia* sp., *Indigofera* sp., *Zornia diphylla*, *Exacum bicolor*, *Torena bicolor*, *Vandellia* spp., *Scutellaria discolor*, *Leucus linifolia*, *Begonia crenata*, *Borreria* sp., *Impatiens* spp. *Hoppea dichotoma*, *Striga* sp., *Rotala* sp., *Phyllanthus maderaspatensis*, *P. urinaria*, and, grasses like *Apluda mutica*, *Kyllinga monocephala*, *Themeda* species and others, are conspicuously noted.

4. The aquatic vegetation.

The lowlands and uplands have many ponds near habitations. Many still water plants are met with here. Water lilies (*Nelumbo nucifera* and *Nymphaea* spp.) are chiefly noticeable with their underwater root stocks and large floating leaves. *Limnanthemum* spp. which resemble these water lilies are also of frequent occurrence. Amongst the hydrophytic aroids *Pistia stratiotes*, a free floating plant, is met with in some of the ponds. Trapaceae is repretented by the free floating *Trapa bispinosa*. Aquatic plants which prefer rather swampy habitat are also quite common and belong to the families Onagraceae and Lythraceae. Species of *Jussieua* (*J. repens*) and *Ludwigia* (*L. parviflora*), *Ammannia* spp., representatives of the genus *Eriocaulon*, *Xyris* spp., and *Hygrophila auriculata* may be mentioned.

5. The riverain vegetation.

The riverain flora is composed of species like *Ficus glomerata*, *Syzygium cumini*, *Terminalia arjuna*, *Schleichera oleosa*, *Bambusa bambos*, *Lagerstroemia speciosa*, *Hopea*

parviflora, Pongamia pinnata, Bassia malabarica (mainly in uplands), *Mangifera indica, Saraca indica* etc. On the river beds inbetween rock boulders *Homonoia riparia, H. retusa,* and often *Phyllanthus lawii, Memecylon umbellatum, Maba nigricans, Eugenia heyneana, Polygonum glabrum* are chiefly observed. *Melastoma malabathricum* is often seen along the edges of streams which may support a dense growth of *Pandanus* spp.

6. The flora of the waste grounds and rice fields.

Many small plants like *Eriocaulon sieboldianum, Geissaspis cristata, Caesulia axillaris, Grangea maderaspatana, Vandellia* and *Bonnaya* spp., *Dentella repens, Canscora decurrens* etc. occupy the wet rice fields ; while the dry ground generally supports *Coldenia procumbens, Heliotropium indicum, Sida spinosa, Triumfetta rhomboides* etc.

The common weeds met with are, *Sida* spp., *Euphorbia hirta, Phyllanthus* spp., *Oldenlandia herbacea, Elephantopus scaber, Blumea* spp., and *Cassia* spp. *Desmodium triflorum, Rangia parviflora Zornia diphyllo, Striga lutea, Centranthera hispida, Drocera indica* amonst others, are often seen in the pastures. Among the plants that have naturalized on wet ground *Amaranthus spinosus, Mimosa pudica, Tridax procumbens, Hyptis suaveolens, Datura fastuosa, Annona squamosa* (near Hunsur), *Jatropha gossypifolia, Scoparia dulcis, Synedrella nudiflora,* and *Lantana camara* may be mentioned.

7. The economic aspect of the flora.

The flora of Coorg district is extremely rich in the variety of economic woods. Veneers of a number of species are put to many uses in plywood industry. The following timbers may be cited as examples :

Adina cordifolia, Ailanthus malabariea, Alstonia scholaris, Artocarpus hirsuta, Calophyllum spp., *Carallia brachiata, Dipterocarpus* spp., *Kydia calycina, Lophopetalum wightianum, Mangifera indica, Spondias mangifera, Pterygota alata, Tectona grandis, Vateria indica, Terminalia* spp., *Trewia nudiflora* and *Zanthoxylum rhetsa.*

Some of the forest species are used in matchwood industry (*Alstonia scholoris, Dipterocarpus turbinatus, Elaeocarpus tuberculatus, Hydnocarpus laurifolia, Macaranga peltata, Symplocos spicata, Salmalia malabarica, Dysoxylum glandulosum, Holigarna arnottiana, Machilus macrantha* and *Vateria indica*) as they yield good splinters and/or boxes. The wood of certain deciduous species like *Bambusa bambos* and *Lannea coromandelica* yields useful pulping material. The wood of *Polyalthia fragrans* is used in construction works while that of *Hopea parviflora* is in great demand for railway sleepers. The over all usefulness of Teak, Rosewood and Sandalwood need not be over stressed.

The medicinal wealth of the flora is enormous. The bark of many plants like *Cinnamomum zeylanicum* and *Holarrhena antidysenteria* ; fruit of *Terminalia chebula, Helicteres isora, Strychnos nux-vomica* etc ; root of *Mussaenda frondosa, Ixora coccinea, Asparagus racemosus, Hemidesmus indicus, Rubia cordifolia, Calycopteris floribunda* are, used medicinally. *Rauvolfia serpentina* is also met with in wild state. Some herbs of medicinal values like *Centella asiatica, Bryophyllum calycinum, Costus speciosus, Ammannia baccifera* and *Oldenlandia corymbosa,* may be cited as examples from the ground flora species.

8. Phytogeographical notes.

The flora presents a strong affinity with the other humid tropics areas. The Indo-Malayan elements of the flora is represented by species of *Mimusops, Carallia, Caryota, Diptercarpus, Garcinia, Ficus, Pothos* etc. Ceylon element is presented by species of *Strychnos, Machilus* and *Myristica* (*M. beddomei*). Most of the species of

genera like *Hapea*, *Glochidon* and *Myristica* are confined to the Western Ghats southwards. The flora though mainly tropical, has a temperate element which prevails at higher elevations near Mercara and on way to Tala Cauveri. Species of *Rubus*, *Rosa*, *Viburnum*, *Hypericum* etc. are met with.

9. *Enumeration of species collected.*

The species collected by the author during different explorations (1957–60) are enumerated below following Benthum-Hooker's system. The plants collected for each family are listed here alphabatically for convenience sake. The sheets for all these plants are located in the herbarium of Western Circle of the Botanical Survey of India, Poona, where this work was carried on. In all 108 families are listed, with 412 genera and 532 species. The plants were collected in flowering/fruiting conditions. The prominent families as regards the number of species as per this list are : *Papilionaceae*, *Rubiaceae*, *Euphorbiaceae*, *Acanthaceae*, *Labiatae*, *Gramineae*, *Moraceae*, *Lauraceae*, *Verbenaceae*, *Solanaceae*, *Meliaceae*, *Rutaceae*, *Malvaceae* and *Tiliaceae*. The systematic census is presented below.

SYSTEMATIC ENUMERATION OF SPECIES COLLECTED AND STUDIED

(Places of collection in Parenthesis)

Ranunculaceae

Clematis gouriana Roxb. (Nagarhole).

Naravelia zeylanica DC. (Kalhalla, Markut, Sampajee).

Dilleniaceae

Dillenia pentagyna Roxb. (Tittimatti).

Magnoliaceae

Michelia champaca Linn. (Bagamandala).

Annonaceae

Annona squamosa Linn. (Hunsur).

Artabotrys zeylanicus Hook. f. & T. (Bagamandala, Makut).

Miliusa tomentosa (Roxb.) J. Sinclair (Nagarhole).

Menispermaceae

Anamirta cocculus W. and A. (Makut).

Cocculus hirsutus (Linn.) Diels (Veeranhosalli).

Coscinium fenestratum Colebr. (Makut).

Diploclisia glaucescens (Bl.) Dalz. (Nagarhole, Sampajee).

Cruciferae

Coronopus didymus (Linn.) Sm. (Mercara).

Capparidaceae

Cadaba farinosa Forsk. (Kalbetta).

Capparis spinosa Linn. (Hunsur).

C. zeylanica Linn. (Mercara).

Violaceae

Rinorea zeylanica (Thw.) O. Kuntze (Bhimagundi, Sampajee).

Bixaceae

Cochlospermum religiosum (Linn.) Alston (Kalbetta, Hunsur).

Flacourtia indica (Burm. f.) Merr. (Kalbetta).

F. montana Grah. (Makut).

Hydnocarpus laurifolia (Dennst.) Sleumer. (Makut, Nagarhole).

Scolopia crenata Clos. (Mercara).

Polygalaceae

Xanthophyllum flavescens Roxb. (Makut).

Caryophyllaceae

Polycarpaea corymbosa Lamk. (Hunsur).

Stellaria media Cyrill (Mercara).

Hypericaceae

Hypericum mysorense Heyne (Bagamandala, Talacauveri).

Hypericum sp. (Bagamandala, Yellow-flowered herb).

Guttiferae

Calophyllum apetalum Willd. (Makut).
C. elatum Bedd. (Makut).
Garcinia indica Chois. (Bagamandala, Makut).
G. talboti Raizada (Makut).
Mesua ferrea Linn. (Bagamandala, Makut).

Ternstroemiaceae

Eurya japonica Thunb. (Bagamandala).
Gordonia obtusa Wall. (Mercara).

Dipterocarpaceae

Dipterocarpus indicus Bedd. (Makut).
Hopea parviflora Roxb. (Makut, Nagarhole).
H. wightiana Wall. (Makut).
Shorea talura Roxb. (Tittimatti).
Vateria indica Linn. (Sampajee).

Ancistrocladaceae

Ancistrocladus heyneanus Wall. (Makut).

Malvaceae

Hibiscus furcatus Roxb. (Makut, Sampajee).
Kydia calycina Roxb. (Tittimatti).
Pavonia zeylanica Cav. (Arabittittu, Hunsur).
Sida acuta Burm.f. (Sampajee, Tittimatti).
S. rhombifolia Linn. (Mercara).
Sida schimperiana Hochst. (Makut, Sampajee).
S. veronicaefolia Lamk. (Kalhalla, Sampajee).
Thespesia lampas Dalz. and Gibs. (Mattigod, Tittimatti).
Urena lobata Linn. (Kalhalla, Mattigod, Tittimatti).

Bombacaceae

Ceiba pentandra (Linn.) Geartn. (Cultivated at Makut).
Salmalia malabarica (DC.) Schott. and Endl. (Kalhalla).

Sterculiaceae

Helicteres isora Linn. (Kalhalla, Tittimatti).
Pterospermum acerifolium Willd. (Makut).
P. rubiginosum Heyne (Makut).
Pterygota alata R.Br. (Makut).
Sterculia guttata Roxb. (Makut).

Tiliaceae

Corchorus triloculoris Linn. (Hunsur).
Grewia heterotricha Mast. (Bagamandala).
G. laevigata Vahl (Kalhalla).
G. tiliaefolia Vahl (Kalhalla, Makut).
G. umbellifera Bedd. (Makut).
Microcos paniculata Linn. (Makut).
Triumfetta rhomboidea Jacq. (Kalhalla, Tittimatti).
T. pilosa Roth (Kalhalla).

Dlaeocarpaceae

Elaeocarpus oblongus Gaertn. (Sampajee).
E. munroii Mast. (Bagamandala).
E. serratus Linn. (Bagamandala).
E. tuberculatus Roxb. (Bagamandala, Makut, Mercara).

Linaceae

Erythroxylum monogynum Roxb. (Hunsur, Kalbetta).
Hugonia belli Sedgw. (Makut).
Linum mysorense Heyne (Mercara).

Malpighiaceae

Hiptage madablota Gaertn. (Kalhalla).

Oxalidaceae

Biophytum sensitivum (Linn.) DC. (Mercara).
Oxalis acetosella Linn. (Mercara).

Balsaminaceae

Impatiens balsamina Linn. (Anechauker, Mercara).
I. kleinii W. and A. (Bagamandala).

Rutaceae

Evodia lunu-ankenda (Gaertn.) Merr. (Kalhalla).
Fagara budranga Roxb. (Makut).
F. tetrasperma (W. and A.) Engl. Bagamandala).

Glycosmis mauritiana (Linn.) Tanaka (Kalhalla, Makut, Mercara, Nagarhole).
Limonia crenulata Roxb. (Nagarhole).
Luvunga eleutherandra Dalz.
Murraya koenigii Spr. (Makut).
M. paniculata (Linn.) Jack. (Nagarhole).
Toddalia asiatica Lamk. (Nagarhole).
Vepris bilocularis Engl. (Makut).

Simarubaceae

Ailanthus excelsa Roxb. (Planted, Makut).
Balanites aegyptiaca (Linn.) Delile (Veeranhosalli).

Burseraceae

Canarium strictum Roxb. (Makut).
Garuga pinnata Roxb. (Kalhalla).

Meliaceae

Aglaia roxburghiana Hiern. (Makut).
Amoora sp. (Makut).
Chukrasia tabularis Adr. Juss. (Kalhalla).
Cipadessa baccifera Miq. (Tittimatti).
Dysoxylum malabaricum Bedd. (Makut).
Heynea trijuga Roxb. (Bagamandala).
Lansium anamallayanum Bedd. (Makut).
Melia composita Willd. (Kalhalla).
Soymida febrifuga Adr. Juss. (Hunsur).
Toona ciliata Roem. (Makut).
Walsura pisida Roxb. (Bagamandala).

Dichapetalaceae

Dichapetalum gelonioides Engl. (Makut).

Olacacae

Apodytes beddomei Mast. (Bagamandala).
Erythorpalam populifolium Mast. (Makut).
Nothapodytes foetida (Wight) Sleumer (Bagamandala).

Icacinaceae

Sarcostigma kleinii W. and A. (Sampajee).

Celastraceae

Celastrus paniculata Willd. (Nagarhole).
Elaeodendron glaucum Pers. (Nagarhole).
Euonymus indicus Heyne ex Wall. (Makut).
Gymnosporia spinosa (Forsk) Fiori (Muthranhosalli).
Lophopetalum wightianum Arn. (Makut).

Rhamnaceae

Gouania microcarpa DC. (Bagamandala, Makut).
Scutia myrtina (Burm.) Kurz (Veeranhosalli, Makut).
Zizyphus oenoplia Mill. (Nagarhole, Tittimitti).
Z. rugosa Lamk. (Nagarhole).
Ventilago maderaspatana Gaertn. (Mercara).

Vitaceae

Cayratia tenuifolia Gagnep (Makut).
Cissus discolor Bl. (Makut).
Leea indica (Burm.) Merr. (Makut).

Sapindceae

Allophyllus serratus Radlk. (Nagarhole).
Cardiospermum helicacabum Linn. (Tittimatti).
Dodonaea viscosa Linn. (Hunsur).
Euphoria longana Lamk. (Bagamandala).
Harpulia arborea (Blanco) Radlk. (Mercara).
Nephelium stipulaceum Bedd. (Bagamadala, Makut).
Schleichera oleosa (Lour.) Merr. (Kalhalla).

Anacardiaceae

Anacardium occidentale Linn. (Makut).
Buchanania lanzan Spr. (Nagarhole).
Holigarna arnottiana Hook.f. (Makut).
H. grahamii Hook.f. (Bagamandala, Makut, Sampajee).
Holigarna sp. (Mercara).
Nothopegia colebrookiana Bl. (Bagamandala, Makut).
Rhus mysorensis Heyne (Kalbetta, Hunsur).
Semecarpus anacardium Linn.f. (Tittimatti).

Connaraceae

Rourea santaloides W. & A. (Mercara).

Papilionaceae

Alysicarpus rugosus DC. (Hunsur).
A. vaginalis DC. (Hunsur).
Atylosia albicans Benth. (Hunsur).
Butea monosperma (Lamk.) Taub. At badly drained sites in lowlands.
Cajanus cajans (Linn.) Millsp. (Nagarhole).
Crotalaria calycina Schr. (Nagarhole).
C. laevigata Lamk. (Tittimatti).
C. retusa Linn. (Nagarhole).
C. striata DC. (Kalhalla, Mercara).
Cylista scariosa Roxb. (Nagarhole).
Dalbergia latifolia Roxb. (Kalhalla).
Desmodium cephalotes Wall. (Kalhalla, Tittimatti).
D. gangeticum DC. (Kalhalla, Nagarhole).
D. motorium (Houtt.) Merrill (Kalhalla).
D. pulchellum Benth. (Kalhalla, Tittimatti).
D. triflorum DC. (Kalhalla).
D. triquetrum DC. (Nagarhole).
Glycine javanica Linn. (Tittimatti).
Indigofera enneaphylla Linn. (Arabittittu, Hunsur).
I. linifolia Retz. (Arabittittu, Hunsur).
Moghania strobilifera (Linn.) St. Hill. ex Jacks. (Kalhalla).
Mucuna sp. (Tittimatti).
Pongamia pinnata (Linn.) Pierre (Tittimatti).
Pseudarthria viscida Linn. f. (Nagarhole).
Pterocarpus marsupium Roxb. (Kalhalla, Tittimatti).
Rycnospora heydsaroides R. Br. (Sampajee).
Rhynchosia albiflora (Sims.) Alston (Konengeri).
R. cana DC. (Mercara).
Shuteria vestita W. and A. (Mercara).
Smithia conferta Sm. (Bagamandala).
S. geminiflora Roth (Bagamandala).
Tephrosia purpurea Pers. (Tittimatti).
T. tinctoria Pers. (Mercara).
Uraria hamosa Wall. (Kalhalla, Tittimatti).

Caesalpiniaceae

Acrocarpus fraxinifolius Wight (Mercara).
Bauhinia racemosa Lamk. (Kalhalla).
Caesalpinia mimosoides Lamk. (Kalhalla).
Cassia auriculata Linn. (Hunsur).
C. fistula Linn. (Kalhalla).
C. hirsuta Linn. (Kalhalla).
C. occidentalis Linn. (Kalhalla, Mercara).
Hardwickia pinnata Roxb. (Makut).
Humboldtia brunonis Wall. (Sampajee).

Mimosaceae

Acacia catechu Willd. (Hunsur).
A. concinna DC. (Kalhalla).
Albizzia chinensis (Osbeck) Merr. (Makut).
A. oboratissima Benth. (Kalhalla).
Mimosa pudica Linn. (Kalhalla, Makut, Sampajee).
Pithecolobium bigeminum Mart. (Bagamandala).
Xylia xylocarpa Taub. (Makut).

Rosaceae

Rosa sp. (Mercara).
Rubus ellipticus Sm. (Mercara).
R. micropetalus Gardn. (Makut).
R. niveus Thunb. (Bagamandala).

Crassulaceae

Bryophyllum pinnatum (Lamk.) Oken. (Bagamandala).

Droseraceae

Drosera burmanni Vahl (Bagamandala).

Rhizophoraceae

Carallia brachiata (Lour.) Merr. (Bagamandala).

Combretaceae

Anogeissus latifolia Wall. (Kalhalla, Tittimatti).
Calycopteris floribunda Lamk. (Makut).
Combretum sp. (Makut).
Terminalia bellerica Roxb. (Attur).
T. paniculata Roth (Kalhalla, Tittimatti).
T. tomentosa W. and A. (Kalhalla, Tittimatti).

Myrtaceae

Eugenia heyneana Duth. (Fraserpet).
Syzygium caryophyllatum (Linn.) Alston (Bagamandala).
S. cumini (Linn.) Skeels (Nagarhole).
S. jambos (Linn.) Alston (Makut).
S. zeylanicum (Linn.) DC. (Nagarhole).

Lecythidaceae

Careya arborea Roxb. (Kalhalla).

Melastomaceae

Melastoma malabathricum Linn. (Bagamandala, Makut).
Memecylon malabaricum Cogn. (Bagamandala).
M. umbellatum Burm. f. (Bagamandala).
Osbeckia cupularis D. Don. (Mercara).
O. truncata D. Don. (Bagamandala, Nagarhole).

Lythraceae

Ammannia baccifera Linn. (Tittimatti).
Ammannia sp. (Kalhalla, Mercara).
Lagerstroemia lanceolata Wall. (Makut).
L. parviflora Roxb. (Tittimatti).
L. speciosa (Linn.) Pers. (Makut).
Rotula indica Koehne (Katekeri).
R. rotundifolia Koehne (Nagarhole).

Onagraceae

Jussiaea perennis (Linn.) Brenan (Kalhalla).
J. repens Linn. (Katekeri).
J. suffruticosa (Linn.) (Attur, Tittimatti).

Passifloraceae

Passiflora foetida Linn. Common.

Caricaceae

Carica papaya Linn. Cultivated, chiefly in lowlands.

Cucurbitaceae

Melothria purpusilla Cogn. (Bagamandala).
Trichosanthes bracteata Voigt. (Makut).

Datiscaceae

Tetrameles nudiflora R.Br. (Makut).

Umbelliferae

Centella asiatica (Linn.) Urban (Mercara, Sampajee).
Pimpinella sp. (Tittimatti).

Araliaceae

Schefflera venulosa Harms (Bagamandala, Makut).

Caprifoliaceae

Viburnum acuminatum Wall. (Bagamandala).
V. coriaceum Bl. (Bagamandala).

Rubiaceae

Adina cordifolia Hook. f. (Makut).
Anotis monosperma Benth. and Hook. f. (Bagamandala).
Borreria hispida (Linn.) K. Sch. (Hunsur).
B. stricta (Linn.) K. Sch. (Hunsur).
Canthium dicoccum (Gaertn.) Merr. (Nagarhole).
Coffea arabica Linn. cultivated.
Gardenia gummifera Linn. f. (Hunsur).
Hymenodictyon excelsum Wall. (Tittimatti).
Ixora arborea Roxb. ex Sm. (Hunsur, Kalhalla).
I. brachiata Roxb. (Makut).
I. polyantha Wight (Sampajee).
I. nigricans Br. (Bagamandala, Mercara).
Knoxia corymbosa Willd. (Tittimatti).
Meyna laxiflora Robyns (Kalhalla).
Mitragyna parvifolia (Roxb.) Korth. (Kalhalla).
Mussaenda glabrata Hutch. (Bagamandala, Makut).
Oldenlandia auricularia K. Sch. (Bagamandala).
O. herbacea Roxb. (Hunsur).
O. nitida Gamble (Bagamandala).
Ophiorrhiza sp. (Bagamandala).
Pavetta indica Linn. (Tittimatti).
Plectronia rheedii Bedd. (Mercara).
Rubia cordifolia Linn. (Kalhalla, Tittimatti).
Tarennia asiatica (Linn.) O. Kuntze (Hunsur).
Wendlandia notoniana Wall. (Kalhalla, Mercara).
Xeromphis spinosa Kery (Kalbetta).

X. uliginosa (Retz.) Mahesh. (Kalhalla).

Compositae

Acanthospermum hispidum DC. (Kalhalla).
Adenostemma lavenia O. Kuntze (Mercara).
Ageratum conyzoides Linn. (Mercara).
Blumea oxyodonta DC. (Mercara).
B. spectabilis DC. (Makut, Sampajee).
Centratherum phyllolaenum Hook. f. (Mercara).
Cosmos sulphureus Cav. (Tittimatti).
Cyathocline purpurea (Don.) O. Kuntze (Nagarhole).
Eclipta prostrata Linn. (Mercara).
Elephantopus scaber Linn. (Mercara, Tittimatti).
Erechthites valerianifolia DC. (Mercara)
Eupatorium odoratum Linn. (Kalhalla).
Grangea maderaspatana Poir (Bagamandala).
Gynura angulosa DC. (Mercara).
Laggera pterodonta Benth. (Nagarhole).
Siegesbeckia orientalis Linn. (Kalhalla, Mercara).
Sphaeranthus indicus Linn. (Kalhalla, Dubare).
Spilanthus acmella Murr. (Kalhalla, Sampajee).
Synedrella nodiflora Gaertn. (Sampajee).
Tridax procumbens Linn. (Makut).
Vernonia cinerea Less. (Mercara, Sampajee).
V. divergens Edgw. (Sampajee, Tittimatti).
V. monosis C.B. Clarke (Mercara).
Vittadenia australis A. Rich. (Mercara).

Companulaceae

Cephalostigma schimperi Hochst. (Mercara).
Lobelia nicotianaefolia Heyne (Makut).

Myrsinaceae

Ardisia solanacea Roxb. (Kalhalla).
Embelia ribes Burm. (Makut).
E. tsjeriam-cottam (Roem. and Sch.) A. DC. (Kalhalla, Tittimatti).
Maesa indica Wall. (Bagamandala, Makut).

Sapotaceae

Donella roxburghii (G. Don) Pierre ex lecomite (Makut, Nagarhole).
Madhuca indica Gmel. (Kalhalla).
Mimusops elengi Linn. (Bagamandala).
Palaquium ellipticum Engler (Makut).

Styraeaceae

Symplocos beddomei CB. Clarke (Makut).

Oleaceae

Jasminum flexile Vahl (Makut).
J. malabaricum Wight (Sampajee).
J. rigidum Zenk. (Hunsur).
J. rottlertanum Wall. (Bagamandala).
Ligustrum perrottetii A. DC. (Mercara).
Linociera malabarica Wall. (Makut).
Olea dioica Roxb. (Kalhalla).

Apocynaceae

Alstonia scholaris R.Br. (Makut).
Beaumontia jerdoniana Wight (Madenad).
Carissa congesta Vahl ; common.
Ervatamia heyneana T. Cooke (Konengeri).
Holarrhena antidysenterica Wall. (Nagarhole, Tittimatti).
Ichnocarpus frutiscens R.Br. (Hunsur).
Rauvolfia densiflora Benth. (Makut-Mercara).
Wrightia tinctoria R.Br. (Anechanker, Nagarhole).
W. tomentosa Roem. and Sch. (Anechanker).

Asclepiadaceae

Asclepias curassavica Linn. (Kalhalla, Tittimatti).
Calotropis gigantea R.Br. (Mercara).
Cryptolepis buchanani Roem. and Sch. (Kalhalla).
Daemia extensa R.Br. (Bagamandala).
Hemidesmus indicus R.Br. (Kalhalla Tittimatti).
Hoya sp. (Virajpet).
Sarcostemma acidum (Roxb.) Voigt (Hunsur).

Loganiaceae

Buddleia asiatica Lour. (Bagamandala).
Fagraea obovata Wall. (Bagamandala).

Gardneria ovata Wall. (Bagamandala).
Strychnos nux-vomico Linn. (Sampajee).
Strychnos sp. (Bagamandala).

Gentianaceae

Canscora decurrens Dalz. ((Makut).
C. diffusa R.Br. (Makut, Tittimatti).
C. perfoliata Lam. (Mercara).
Exacum bicolor Roxb. (Bagamandala).

Boraginaceae

Cordia macleodii Hook. f. and T. (Veeranhosalli).
Cordia myxa Linn. (Konengari, Nagarhole).
Cynoglossum denticulatum A. DC. (Mercara, Kalhalla).
Ehretia buxifolia Roxb. (Hunsur).
E. laevis Roxb. (Kalhalla).
Heliotropium indicum R.Br. (Hunsur).
Rotula aquatica Lour. (Makut).
Trichodesma indicum R.Br. (Hunsur).

Convolvulaceae

Argyreia cuneata Ker-Gawl. (Hunsur, Kalhalla).
A. elliptica Choisy (Bagamandala).
Erycibe paniculata Roxb. var. *wightiana* C.B. Clarke (Bagamandala).
Ipomoea aquatica Forsk. (Tittimatti).
Merremia umbellata Hallier f. (Sampajee).

Solanaceae

Browelia demisa Linn. (Mercara).
Datura metal Linn. (Mercara).
Nichandra physaloides Gaertn. (Kalhalla).
Solanum ferox Linn. (Mercara).
S. giganteum Jacq. (Kalhalla).
S. indicum Linn. (Kalhalla, Makut).
S. nigrum Linn. (Kalhalla).
S. torvum Swertz. (Sampajee).
S. verbasifolium Linn. (Hunsur).
Solanum sp. (Hunsur).

Scrophulariaceae

Artanema sesamoides Benth. (Kalhalla).
Buchnera hispida Ham. (Hunsur).
Centranthera hispida R.Br. (Bagamandala).
Ilysanthes veronicaefolia Urban (Bagamandala).
Moniera cuneifolia Michx. (Mercara).
Scoparia dulcis Linn. (Kalhalla).
Sopubia delphinifolia G. Don. (Hunsur).
Torenia bicolor Dalz. (Bagamandala).

Gesneriaceae

Aeschynanthus perrottetii A. DC. (Bagamandala).

Bignoniaceae

Dolichandrone atrovirens Sprague (Kalhalla, Nagarhole).
Pajanelia multijuga DC. (Makut).
Stereospermum tetragonum DC. (Mattigod, Tittimatti).

Acanthaceae

Adhatoda vasica Nees (Makut).
Asteracantha longifolia Nees (Kalhalla).
Asystasia chelonoides Nees (Bagamandala).
Barleria buxifolia Linn. (Hunsur).
B. involucrata Nees (Bagamandala).
Blepharis asperrima Nees (Hunsur).
B. maderaspatensis (Linn.) Heyne ex Roth. (Mercara-Fraserpet).
Carvia callosa (Nees) ex Bremek. (Makut).
Eranthemum montanus Roxb. (Sampajee).
E. purpurascens Nees (Kalhalla).
Justicia betonica Linn. (Mercara, Tittimatti).
J. procumbens Linn. (Bagamandala, Mercara).
Lepidagathis incurva G. Don. (Mercara, Sampajee).
Micranthus oppositifolius Wend. (Nagarhole).
Nilgirianthus barbatus (Nees) Bremek. (Mercara).
Peristrophe bicalyculata Nees (Hunsur, Kalhalla).
Rungia parviflora Nees var. *pectinata* CB. Clarke (Kalhalla, Mercara).
Thunbergia alata Boigr. ex Sims (Tittimatti).
T. fragrans Roxb. (Tittimatti).
T. mysorensis T. Anders (Makut).

Verbenaceae

Callicarpa tomentosa (Linn.) Murr. (Makut).

Clerodendrum serratum (Linn.) Moon. (Tittimatti).
C. viscosum Vent (Makut, Sampajee).
Gmelina arborea Roxb. (Kalhalla, Makut).
G. asiatica Linn. (Nagarhole).
Lantana camara Linn. var. *aculeata* Moldenke (common).
Phyla nodiflora (Linn.) Greene (Hunsur).
Premna coriacea CB. Clarke (Kalhalla).
Stachytarpheta indica Vahl (Kalhalla, Sampajee).
Tectona grandis Linn. f. common in lowlands.
Vitex altissima Linn. f. (Tittimatti).
V. negundo Linn. (Mercara).

Labiatae

Anisomeles indica O. Kuntze (Tittimatti).
Colebrookea oppositifolia Smith (Makut).
Dysophylla auricularia Bl. (Nagarhole).
Gomphostemma heyneanum Wall. (Kalhalla).
Hyptis suaveolens Poit. (Bagamandala, Makut).
Leucas ciliata Benth. (Mercara, Sampajee).
L. lavandulaefolia Rees. (Sampajee).
L. mollissima Wall. (Bagamandala).
L. stelligera Wall. (Mercara).
Orthosiphon diffusus Benth. (Hunsur).
O. glabratus Benth. (Kalhalla, Nagarhole).
Plectranthus mollis (Ait.) Spreng. (Tittimatti).
Pogostemon paniculatus Benth. (Kalhalla).
P. Plectranthoides Desf. (Makut, Marcara).
Pogostemon sp. (Bagamandala).
Teucrium tomentosum Heyne (Mercara).

Plantaginaceae

Plantago asiatica Linn. (Mercara).

Amaranthaceae

Achyranthes aspera Linn. (Kalhalla, Nagarhole).
Aerva monsoniae Mart. (Hunsur).
Alteranthera triandra Lamk. (Kalhalla).
Amaranthus spinosus Linn. (Kalhalla).
Cyathula prostrata Bl. (Nagarhole, Sampajee).

Chenopodiaceae

Chenopodium ambrosiodes Linn. (Kalhalla).
C. murale Linn. (Mercara).

Polygonaceae

Polygonum chinense Linn. (Mercara, Tittimatti).
P. glabrum Willd. (Kalhalla, Mercara).
P. plebegum R.Br. (Hunsur, Makut).

Artistolochiaceae

Aristolochia brachiata Retz. (Makut).
Bragantia wallichii R.Br. (Makut).

Piperaceae

Heckeria subpeltata Kunth (Makut).
Pepromia pellucida H. B. and K. (Sampajee).
P. tetraphylla Hook. and Arn. (Mercara).
Piper nigrum Linn. (Bagamandala, Sampajee).

Myristicaceae

Knema attenuata Warb. (Makut).
Myristica beddomei King. (Makut).

Lauraceae

Alscodaphne semecarpifolia Nees (Bagamandala).
Cassytha filiformis Linn. (Hunsur).
Cinnamomum zeylanicum Bl. (Mercara, Sampajee).
Cryptocarya bourdillonii Gamble (Mercara).
Litsaea deccanensis Gamble (Bagamandala).
L. stocksii Hook. f. (Bagamandala).
L. wightiana Benth. and Hook f. (Bagamandala, Mercara, Nagarhole).
Machilus macrantha Nees (Kalhalla, Makut).
Neolitsaea zeylanica Merr. (Bagamandala, Makut).
Phoebe sp. (Makut).

Proteaceae

Helicia nilagirica Bedd. (Bagamandala).

Elaeagnaceae

Elaeagnus conferta Roxb. (Bagamandala).

Loranthaceae

Macrosolen parasiticus (Linn.) Danser. (Bagamandala).
Taxillus cuneatus (Roth) Danser. (Bagamandala).
Viscum orientale Willd. (Murkal).

Buxaceae

Sarcococca trinervia Wight (Mercara).

Euphorbiaceae

Aporosa lindleyana Baill. (Nagarhole).
Antidesma diandrum Roth. (Nagarhole).
A. ghaesembilla Gaertn. (Kalhalla).
A. menasu Miq. (Makut, Nagarhole).
Baccaurea courtallenis Muell.—Arg. (Sampajee).
Baliospermum montanum Muell.—Arg. (Kalhalla).
Bischofia javanica Linn.
Bridelia squamosa Gehrm. (Hunsur).
B. stipularis Bl. (Nagarhole).
Cyclostemon confertiflorus Hook. f. (Makut).
Emblica officinalis Gaertn. (Kalhalla).
Euphorbia hirata Linn. (Hunsur).
E. rothiana sp. (Mercara).
Glochidion sp. (Mercara).
Havea brazilliensis Muell.—Arg. (Makut).
Hemicyclea venusta Thw. (Makut).
Homonoia retusa Muell.—Arg. (Makut).
H. riparia Lour. (Makut).
Kirjanelia reticulata Baill. (Mercara).
Macaranga peltata Muell.—Arg. (Sampajee, Makut).
Mallotus albus Muell.—Arg. (Makut).
M. aureopunctatus Muell.—Arg. (Makut).
M. philippensis Muell.—Arg. (Makut, Nagarhole).
Melanthesa turbinata (Koen. ex Roxb.) Oken. (Kalhalla).
Sapium insigne Benth. (Sampajee).
Securinega leucopyrus (Willd.) Muell.—Arg. (Makut).
Tragia involucrata Linn. (Makut).
Trewia nudiflora Linn. (Makut).

Ulmaceae

Cellis tetrandra Roxb. (Bagamandala).
Trema orientalis Bl. (Kalhalla).

Moraceae

Antiaris toxicaria Leschen. (Makut).
Artocarpus hirsuta Lamk. (Makut).
A. heterophyllus Lamk. (Kalhalla, Makut).
Ficus asperrima Roxb. (Bagamandala, Makut).
F. callosa Willd. (Bagamandala).
F. Gibbosa Bl. (Bagamandala.)
F. glomerata Roxb. (Mercara).
F. hispida Linn. (Makut, Nagarhole).
F. lacor Buch.—Ham. (Nagarhole).
Plecospermum spinosum Trec. (Bagamandala).
Streblus asper Lour. (Tittimatti).

Urticaceae

Boehmeria malabarica Wedd. (Makut).
Debregeasia velutina Gaud. (Makut-Virajpet).
Elatostemma lineolatum Wight (Bagamandala).
Girardinia leschenaultiana Dcne. Nagarhole).
Pilea microphylla Liebm. (Mercara).
Pouzolzia pentandra Benn. (Makut, Mercara).

Salicaceae

Salix tetrasperma Roxb. (Virajpet).

Orchidaceae

Bulbophyllum neilgherrense Wight (Mercara).
Liparis longipes Lindl. (Sampajee).
Oberonia recurva Lindl. (Mercara).
Pholidota imbricata Lindl. (Mercara).

Zingiberaceae

Costus speciosus Sm. (Kalhalla).
Elettaria cardamomum Maton (Sampajee).

Amaryllidaceae

Curculigo orchioides Gaertn. (Bagamandala).

Dioscoreaceae

Dioscorea oppositifolia Linn. (Sampajee).

D. pentaphylla Linn. (Bagamandala).

Liliaceae

Asparagus racemosus Willd. (Nagarhole).
Dracaena terniflora Roxb. (Makut).
Smilax zeylanica Linn. (Bagamandala, Kalhalla, Makut, Nagarhole).

Pontederiaceae

Monochoria vaginalis Presl. (Attur).

Xyridaceae

Xyris indica Linn. (Bagamandala).

Commelinaceae

Aneilema scapiflorum Wight (Tittimatti).
Commelina nudiflora Linn. (Tittimatti).
Floscopa scandens Lour. (Mercara).

Palmeae

Caryota urens Linn.

Araceae

Arisaema tortuosum Schott. (Bagamandala).
Colocasia antiquorum Schott. (Kalhalla).
Lagenandra ovata Thw. (Kalhalla).
Pistia stratiotes Linn. (Mercara).
Pothos scandens Linn. (Makut, Sampajee).

Eriocaulaceae

Eriocaulon robusto-brownianum Ruhl. (Bagamandala).

Cyperaceae

Eleocharis chaetaria Roem. and Sch. (Mercara).
Kyllinga triceps Rottb. (Mercara).

Gramineae

Apluda mutica Linn. (Hunsur).
Aristida adscensionis Linn. (Hunsur).
Arthraxon lancifolius Hochst. (Mercara).
Arundinella sp. (Mercara).
Brachiaria reptans (Linn.) Gard. (Hunsur).
Cappilipedium sp. (Mercara).
Centotheca lappacea Desv. (Makut).
Coix lacryma-jobi Linn. (Nagarhole).
Dimeria ornithopoda Trin. (Mercara).
Eragrostis unioloides Nees (Mercara).
Heteropogon contortus Beauv. ex R. and S. (Hunsur, Mercara).
Imperata cylindrica (Linn.) Beauv. (Kalhalla).
Ischne dispar Trin. (Mercara).
I. elegans Dalz. (Sampajee).
Junsenella griffithiana Bor (Mercara).
Oplismenus compositus Beauv. (Sampajee).
Sacciolepis interrupta Stapf. (Nagarhole, Sampajee).
Setaria palledifusca Stapf. *et* E. E. Hubbard (Kalhalla).

Summray :

The paper deals with the different aspects of the botany of Coorg laying emphasis on the following features : (1) The flora of the lowlands ; (2) The flora of the uplands ; (3) The monsoon flora ; (4) The aquatic vegetation ; (5) The riverain vegetation ; (6) The flora of the waste grounds and rice fields ; (7) The economic aspect of the flora ; (8) Phytogeographical notes ; and (9) Enumeration of the species collected. A systematic list of 532 plant species belonging to 108 families is presented.

Acknowledgements :

The author is grateful to C. S. I. R. for the provision of a fellowship during these studies. He is equally indebted to the forest officers of the districts for the help given in exploration work and to Dr. S. K. Mukherjee, Keeper, Central National Herbarium for some identifications.

References :

Arora, R. K. *Botanical and ecological studies in the humid tropics*. Ph.D. Thesis Panjab University (unpublished), 1960.

——— The botany of Coorg forests. *I. Proc. Nat. Acad. Sci. India.* **30**B (III) : 289–305, 1960.

——— Ecological notes on the vegetation of Coorg district, Western Ghats, India, *Indian For.* (in press) 1964.

A *FUSARIUM* WILT OF *VINCA ROSEA* LINN.

By

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[Received on 18th July, 1961]

In August 1954 some plants of *Vinca rosea* Linn. with white flowers growing in a residential garden and also in the Botanical Garden of Agra College, showed symptoms of wilt soon after heavy showers of rain. Close examination revealed that almost all the plants were in various stages of wilting. Peculiar enough, the plants with pink flowers growing mixed with those bearing white flowers did not wilt, but during the wet season of 1955 and afterwards both the varieties of the host plants were similarly affected. Isolations and pathogenicity tests established a case of *Fusarium* wilt which is described here.

Symptomatology :

When seedlings are affected wilting is fairly sudden, but most often in adult host plants it is gradual. The leaves are first affected, become flaccid ; show signs of yellowing and finally drop off defoliating the branches, which show distinct symptoms of wilting and withering (Fig. I). In well branched old plants the wilting is first confined only to a few branches, the rest of the plant remaining normal for some time but ultimately the entire plant is overtaken by the disease and wilts. In these plants wilting starts in acropetal succession (Fig. II). The 'vein clearing' phenomenon as observed in cotton wilt (Kalyansundram, 1954) is a very characteristic symptom in the present case also, probably more so because the healthy leaves are prominently veined in members of Apocynaceae. Before symptoms appear leaves of the affected plants give a comparatively feeble Sach's starch test. As the disease progresses characteristic wrinkles appear on the bark of the stem extending from the base upwards. Probably due to the wet season (July—September) the wrinkled bark ultimately peels off as a thin mass of wet-rot tissue exposing the wood. In quite a number of affected plants of the white flowering variety masses of sporodochia were found on the surface of the stem particularly about the middle of the branches. Mature sporodochia were cream in colour while the younger ones, occuring towards the apex of the branch, pinkish. The occurence of sporodochia on host plants is not a common feature in *Fusarium* wilts and therefore, all the more interesting in the present case. The affected plants could be easily pulled out of the ground, the root showing signs of decay and rot. The affected roots are blackened, the entire cortex of the main tap-root peeling off and disintegrating. The younger lateral branches show normal appearance showing that it takes some time for the fungus to attack the young roots. The cortex, both of the stems and roots, contain abundant hyphae which also extend to the wood and were found to accumulate in the vessels. In the healthy lateral branches of affected plants no mycelium was detected.

Pathogenicity :

Pure culture isolates of the pathogen were obtained from roots and stems of both the white and pink varieties of the host and also from the sporodochia

produced on the stem of white variety. Standard mycological techniques were employed to establish pathogenicity. The three isolates thus obtained were grown in sand-cornmeal medium in conical flasks to obtain sufficient amount of inoculum for testing pathogenicity. The inoculum was mixed with partially sterilized garden soil in glazed disinfected earthern pots in the ratio of 1 : 10 as suggested by Subramanian (1952). Three days after inoculation of the soil seedlings of white and pink floweeing varieties of the host, grown in uncontaminated soil, were transplanted to the infested pots. Controls in uninfested pots were also kept. The pots were kept in a glass house. Confirmation of the pathogenicity was made by reisolating the respective fungus strains from the affected plants of the experiment. The results of the pathogenicity experiments are summarised in table I.

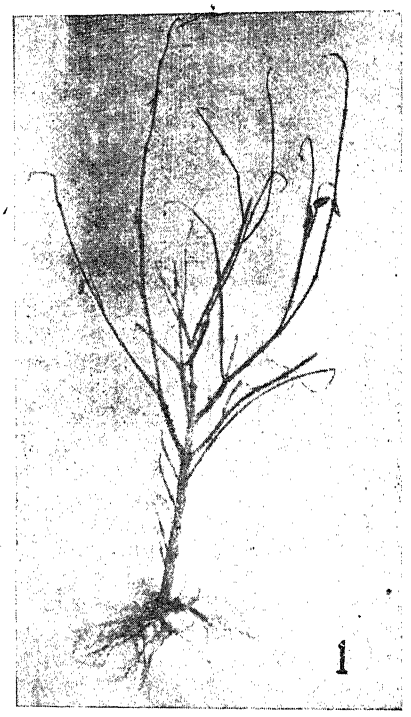

Fig. 1

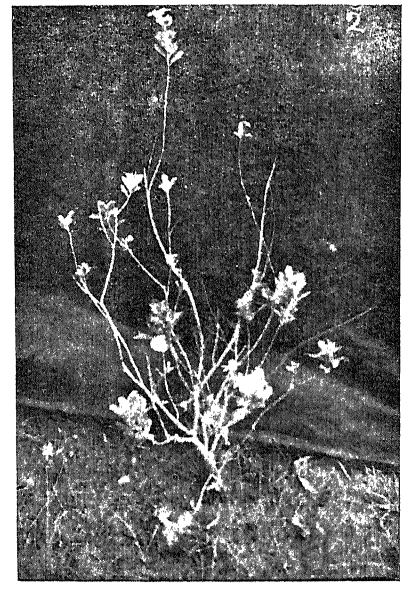

Fig. 2

Results of the above experiment confirm the pathogenicity of the three isolates, and it is interesting to note that isolates 1 and 2 obtained from white flowering variety do not infect pink flowering variety of the host and isolate 3 from pink flowering variety does not infect the white flowering variety.

Identity and characteristics of the pathogens :

All the three isolates belong to the genus *Fusarium* but pathogenicity and cultural experiments (Table II) indicate differences among them.

TABLE I

Showing results of pathogenicity tests

Isolates	White flowering variety of *Vinca rosea*				Pink flowering variety of *Vinca rosea*			
	Inoculated soil		Control		Inoculated soil		Control	
	No. of plants grown	No. of plants wilted	No. of plants grown	No. of plants wilted	No. of plants grown	No. of plants wilted	No. of plants grown	No. of plants wilted
Isolate No. 1 (from white flowering variety)	15	12	5	Nil	15	3*	5	Nil
Isolate No. 2 (from sporodochia formed on white flowering variety	20	15	5	1*	20	Nil	5	Nil
Isolate No. 3 (from pink flowering variety)	20	Nil	5	Nil	20	16	5	Nil

*These did not yield any organism.

TABLE II

Showing cultural characteristics of the three isolates of *Fusarium*

Isolates	Type of colony		Type of mycelium		Dry weight of mycelium	Growth in diameter 12 days after	Colour reaction on steamed rice after 20 days (Maerz & Paul)
	Solid medium	Liquid medium	Solid medium	Liquid medium			
Isolate No. 1	Flat	Aerial	Cottony	Cottony	0·133 gm	52·5 mm	Redish violet red becoming brown. Plate 46 L/7 Page 115.
Isolate No. 2	Flat	Centre aerial	Cottony	Cottony villose	0·194 gm	69·6 mm	Top : Pinkish violet. Plate 54 F/5 Page 131 Bottom : Bluish violet. Plate 46 A/9 Page 115
Isolate No. 3	Flat	Aerial	Cottony	Cottony	0·105 gm	50·8 mm	Pinkish violet pink becoming deep. Plate 46 F/7 Page 115

The type of mycelium and colony appear almost the same in all the three isolates. They, however, differ in the dry weight of mycelium. In matter of growth rate isolate 1 and 3 are similar while isolate 2 grows faster. Colour reaction on steamed rice (Padwik 1940*a*, 1940*b* and Maerz and Paul, 1950) indicates good valid differences among the organisms. Morphological comparisons of shape and ize of microconidia of the three isolates again offer evidence for their being distinsct from one another. The microconidia of the isolates from white and pink varieti es and the sporodochial isolate have length and breadth ratios of 3·365μ, 3·647μ, 3·910μ (mean of 100 values significant at 1% level), respectively.

The three isolates under study have been identified as mutant types of *Fusarium solani* (Mart.) App. and Wr. for which authors are thankful to Dr. William C. Snyder of the University of California, U.S.A.

Summary :

A *Fusarium* wilt of white and pink flowering varieties of *Vinca rosea* Linn is described. Three mutant types of *Fusarium solani* (Mart.) App. and Wr. are reported, one causing wilt of the pink variety and unable to attack the white variety and two others affecting the white variety but not the pink, One of the mutant types causing wilt of the white variety forms sporodochia on the host surface, a feature of unusual interest.

Cultural characteristics of the three strains have been studied and pathogenicity tests performed.

References :

Kalyansundaram, R. Soil condition and root diseases XIII. Symptomatology of *Fusarium* wilt. *Jour. Indian Bot. Soc.* **33** : 329–337, 1954.

Maerz, A. and Rea Paul, M. *A Dictionary of Colour.* McGraw Hill-Book Company, Inc., London, 1950.

Padwick, G. W. The genus *Fusarium* III. A critical study of the funguy causing wilt of gram (*Cicer arietinum* L.) and of related species in the sub-section *Orthocera* with special relation to the variability of kes characteristics. *Indian, Jour. Agri. Sci.*, **10** : 241–284, 1940*a*.

——— The genus *Fusarium* V. *Fusarium udum* Butler *Fusarium vasinfectum* Atk. and *Fusarium laterium* Var. *uncinatum* Wr. *Ibid.*, **10** : 863–878, 1940*b*.

Subramanian, C. V. Studies on South Indian *Fusaria* II. *Fusaria* isolated from black cotton soils. *Proc. Nat. Inst. Sci. India*, **18** : 557–584, 1952.

CONTRIBUTION TO THE EMBRYOLOGY OF THE GENUS *PHYLLANTHUS* LINN.

By

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Introduction :

In 1937 Maheshwari and Chowdry described the development of the female gametophyte in *Phyllanthus niruri*. These authors demonstrated that the development of the embryo sac in this species is of the monosporic type but due to the early degeneration of the antipodals the mature embryo sac appears to be 4–nucleate. They also reported the presence of an obturator in this species. Banerji and Dutt (1944) confirmed the observations of Maheshwari and Chowdry (1937) with regard to the development and organisation of the mature embryo sac but at the same time denied the presence of an obturator in *Phyllanthus niruri*. The authors studied three more species of this genus, viz., *Phyllanthus maderaspatensis* L., *P. urinaria* L. and *P. simplex* Retz., growing round about Nagpur and our observations with regard to the absence of the obturator agree with those of Banerji and Dutt (1944). These are described in the present communication along with other detailed observations on the life history of these species.

For literature reference may be made to the papers of Thathachar (1953), Johri and Kapil (1953), Kapil (1956) and Mukherjee (1957, 1961).

Material and Methods :

The material was fixed locally in formalin-acetic-alcohol. Routine methods of dehydration and embedding were followed. Sections were cut 10–12μ thick, stained in iron alum haematoxylin and destained in a saturated solution of picric acid. A few slides were also counterstained with fast green. The external features of the pollen grains were studied after mounting them in methyl green glycerin jelly (Wodehouse, 1959).

Microsporogenesis, Male gametophyte and pollen grain :

The anthers are bithecous. The archesporium appears at four places ands consist of 2 or 3 rows of hypodermal cells (Figs. 1, 2). The archesporium divider periclinally forming a primary parietal layer and a primary sporogenus layer (Fig 2.). The former divides to form two layers (Fig. 3). The resulting innee layer divides again periclinally forming in all three parietal layers (Fig. 4). Thr layer adjacent to the sporogenous cells forms the tapetum, the hypodermal laye. develops into the fibrous endothecium while the middle layer degenerates (Fig. 5) The epidermal cells at maturity become flattened. The dehiscence of the anther is similar to that of *Euphorbia dracunculoides* (Mukherjee, 1961).

The tapetal cells, to begin with, are full of cytoplasm. During meiosis of the microspore mother cells the nucleus in each tapetal cell divides mitotically and the cells become binucleate. The tapetum is of the secretory type. The yellow staining globules are noted on the inner tangential wall of the tapetal cells soon

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after the pollen grains are formed. Such globules appear also on the fibrous endothecium (Fig. 6) as in *Kirganelia reticulata* (Deshpande, 1959). These globules on the endothecium are sparsely deposited at about the uni-nucleate stage of the pollen grains but in the mature anther their number increases considerably.

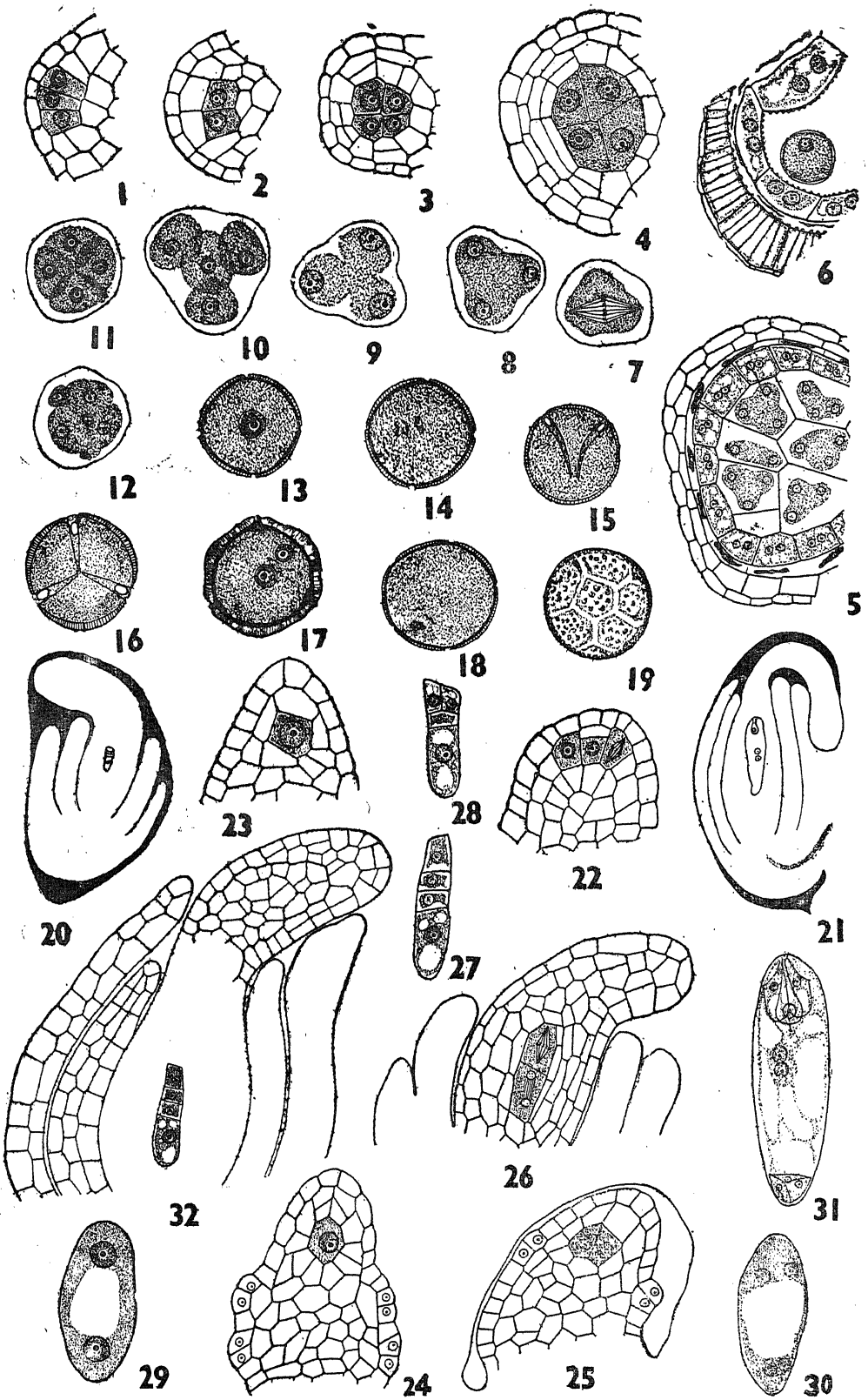
The primary sporogenous cells divide mitotically to increase their number. Each microspores mother cell undergoes two meiotic divisions and forms four microspores (Fig. 7, 8). Cytokinesis is by furrowing (Fig. 9). The young microspores are arranged tetrahedrally (Fig. 10). Sometimes their arrangement is also isobilateral (Fig. 11). A case of polyspory was noticed in *Phyllanthus maderaspatensis* where six microspores were formed from a single microspore mother cell (Fig. 12). The exact case of their formation is not known. Such instances of polyspory are not uncommon in angiosperms and are met with in *Cuscuta reflexa* (Johri and Tiagi, 1952), *Solanum macranthum* (Prakash and Chatterjee, 1953), *Lantana camara* (Tandon and Bali, 1955), *Justicia simplex* (Ram and Sehgal, 1958) *Naregamia alata* (Nair, 1959) etc.

The young pollen grains are full of cytoplasm and they soon develop exine and intine. The former is striated and is much thicker in *Phyllanthus maderaspatensis* than in the other two species of this genus (Fig. 17). The intine is a thin delicate membrane (Figs. 14, 17, 18). The pollen grains in *Phyllanthus maderaspatensis* are tricolporate (Figs. 16, 17) while in *P. urinaria* they are tetracolporate (Figs. 13–15). In *P. simplex* the pollen grains are synrugoidorate surrounding pentangular areoles and are provided with 20 rugoid streaks (Fig. 19). Banerji (1951) reports a central band with a single germ pore in *P. reticulatus*. In *P. urinaria* and *P. simplex* the pollen grains are 3-celled at anthesis (Figs. 14, 18) and their tube nucleus presents a lobed appearence. It is also darkly stained. In *P. maderaspatensis*, on the other hand, the pollen grains are 2-celled at anthesis (Fig. 17). In all the three species the pollen grains have an abundant deposit of starch grains in them.

Ovule :

The gynoecium is tricarpellary, syncarpous and trilocular. Each loculus contain two ovules hanging down from the axile placenta. The ovules are bitegmic and crassinucellate (Fig. 20, 21). The uper part of the nucellus in all the three species develops into a nucellar beak, a feature shared by several other members of the family (*See* Banerji and Dutt, 1944; Kapil, 1956; Mukherjee, 1957 and Deshpande, 1959). In the formation of nucellar beak the epidermis also contributes its own share (Fig. 32) as in *Kirganelia reticulata* (Deshpande, 1959). At about the tetrad stage the nucellar beak protrudes out of the micropyle (Figs. 20, 32) as in *P. niruri* (Banerji and Dutt, 1944) and by the time the embryo sac reaches maturity the nucellar beak curves down conspicuously towards the placenta in the form of an inverted U (Fig. 21). The tip of the nucellus is slightly swollen as in *Croton bonplandianum* (Mani, 1960).

There is no formation of the obturator in the three species of *Phyllanthus* described in this paper. Maheshwari and Chowdry (1937), however, have reported the presence of obturator in *P. niruri*. Banerji and Dutt (1944) on the other hand have stated that there is no formation of the obturator in this species. In the light of our observations on the other species of *Phyllanthus*, we are inclined to agree with the observation of Banerji and Dutt (1944) on the absence of obturator in *P. niruri*.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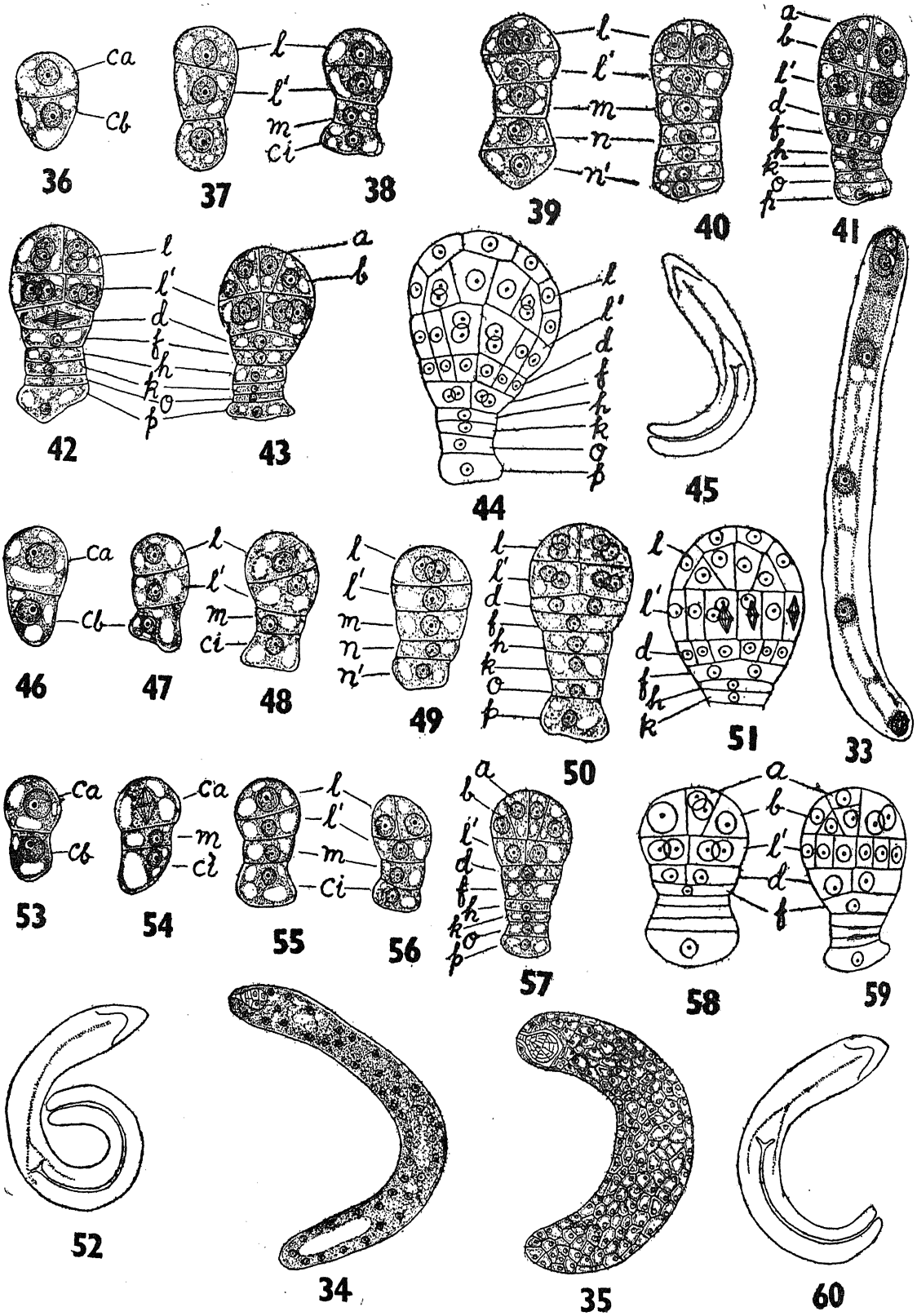
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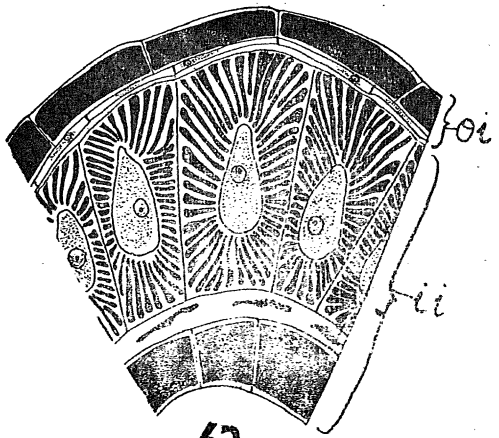

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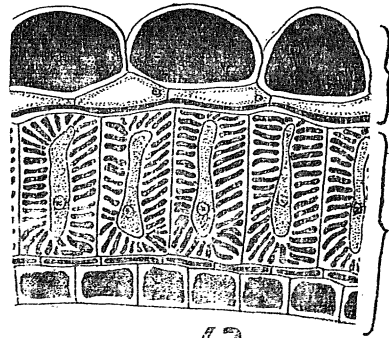

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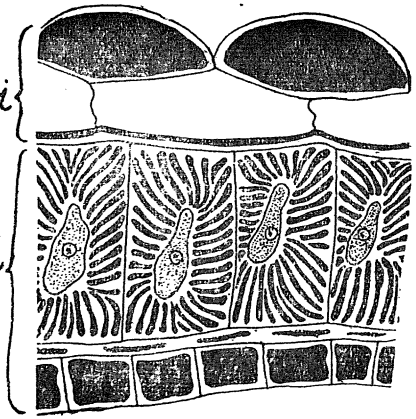

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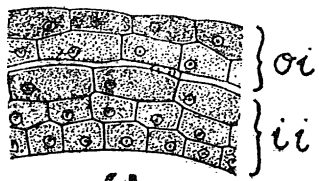

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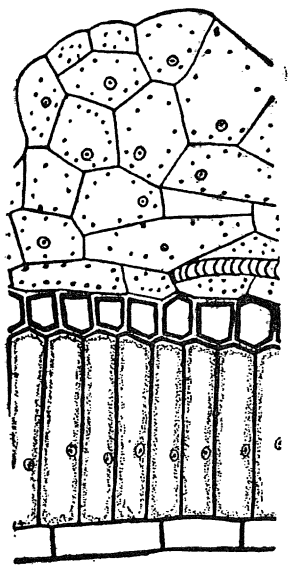

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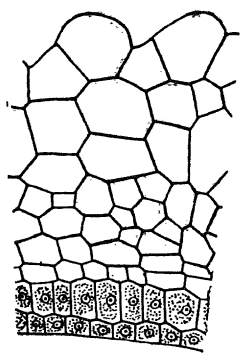

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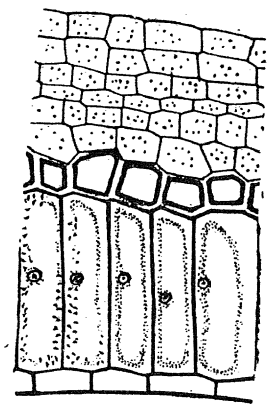

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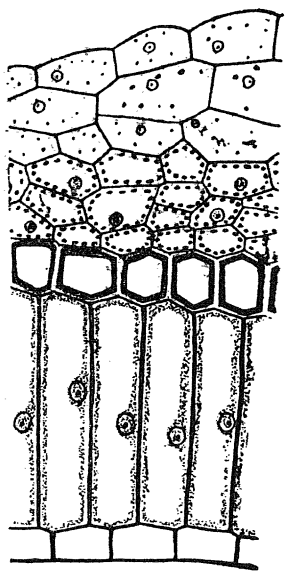


68

EXPLANATION OF FIGURES

Plate 1

Figs. 1-3 ; 7, 11, 12, 16, 17, 22, 26, 27, 30, 32. *Phyllanthus maderaspatensis*. Fig. 1. T.S. part of anther lobe showing multicellular archesporium. X600. Fig. 2. The same showing parietal cells and microspore mother cells X600. Fig. 3. The same showing development of anther wall. X600. Fig. 7. Pollen mother cell showing meiosis I. X800. Fig. 11. Isobilateral arrangement of young pollen grains. X800. Fig. 12. Pollen mother cell showing polyspory. X800. Fig. 16. Tricolporate pollen grain. X800. Fig. 17. 2-celled pollen grain. X800. Fig. 22. V.S. part of nucellus showing multicellular archesporium. X600. Fig. 26. The same showing dyad. X600. Fig. 27. A linear tetrad. X600. Fig. 30. 4-nucleate embryo sac. X600. Fig. 32. V.S. ovule showing formation of nucellar beak and epidermal cap. X500. Figs. 5, 8, 10, 18-21 ; 25, 28. *Phyllanthus simplex*. Fig. 5. T. S. anther lobe showing epidermis, hypodermis, degenerating middle layer and bi-nucleate tapetum. X600. Fig. 8. Pollen mother cell showing cytokinesis. X800. Fig. 10. Tetrahedral arrangement of young pollen grains. X800 Fig. 18. 3-celled pollen grain. X800. Fig. 19. Surface view of pollen grain showing pentangular areoles with rugoid streaks. X800. Fig. 20. V.S. ovule at the tetred stage. X250. Fig. 21. The same at the mature embryo sac stage showing curved nucellar beak. X150. Fig. 25. V.S. nucellus showing 2 megaspore mother cells with parietal cells. Note the origin of inner integument initials. X600. Fig. 28. T-shaped tetrad. X600. Figs. 4, 6, 9, 13-15 ; 23, 24, 29, 31. *Phyllanthus urinaria*. Fig. 4. T.S. anther lobe showing anther wall and microspore mother cells. X600. Fig. 6. The same showing tangentially flattened epidermis, fibrous endothecium, degenrating middle layer and bi-nucleate tapetum. Note the presence of yellow staining granules on the tapetum and fibrous endothecium. X600. Fig. 9. Pollen mother cell showing cytokinesis. X800. Fig. 13. Uni-nucleate pollen grain. X800. Fig. 14. 3-celled pollen grain. X800. Fig. 15. Surface view of the pollen grain showing only 2 out of 4, colpi note the presence of pore. X800. Fig. 23. V.S. part of nucellus showing megaspore mother cell and a parietal cell. X800. Fig. 24. The same as above. Note the origin of both the integuments. X800. Fig. 29. 2-nucleate embryo sac. X800. Fig 31. Mature embryo sac. X800.

Plate 2

Figs. 33 ; 36-45. *Phyllanthus urinaria*. Fig. 32. Embryo sac showing 2-celled pro-embryo and 4 free endosperm nuclei. X800. Figs. 36-44. Stages in the development of embryo. X800. Fig. 45. L.S. mature embryo. X30.

Figs. 34, 35 ; 46-52. *Phyllanthus maderaspatensis*. Figs. 34, 35. Stages in the development of endosperm. X120. Figs. 46-51. Stages in the development of embryo. X800. Fig. 52. L.S. Mature embryo. X30.

Figs. 53-60. *Phyllanthus simplex*. Figs. 53-59. Stages in the development of embryo. X800. Fig. 60. L.S. mature embryo. X30.

Plate 3

Figs. 61, 64, 67. *Phyllanthus maderaspatensis*. Fig. 61. L.S. part of integuments. X600. Fig. 64. L.S. part of mature testa. X600. Fig. 67. L.S. part of pericarp. X600. For details see taxt.

Figs. 62, 66. *Phyllanthus urinaria*. Fig. 62. L.S. part of mature testa. X600. Fig. 66. L.S. part of pericarp. X600. For details see text.

Figs. 63, 65, 68. *Phyllanthus simplex*. Fig. 63. L.S. part of mature testa. X600. Fig. 65. L.S. part of pericarp at mature embryo sac stage. X600. Fig. 68. L.S. part of mature pericarp. X600. For details see text. *ii*, inner integument, *oi*, outer integument.

As stated previously the ovules have two integuments. The outer integument is uniformly two layered while the inner one becomes three layered due to the periclinal divisions of the inner epidermis (Fig. 32). In *P. urinaria* the initials of the integuments are visible at the megaspore mother cell stage (Fig. 24) while in the other two species only the initials of the inner integument are formed at this stage (Fig. 25). The initials of the outer integument appear at a slightly later stage.

Megasporogenesis and Female gametophyte :

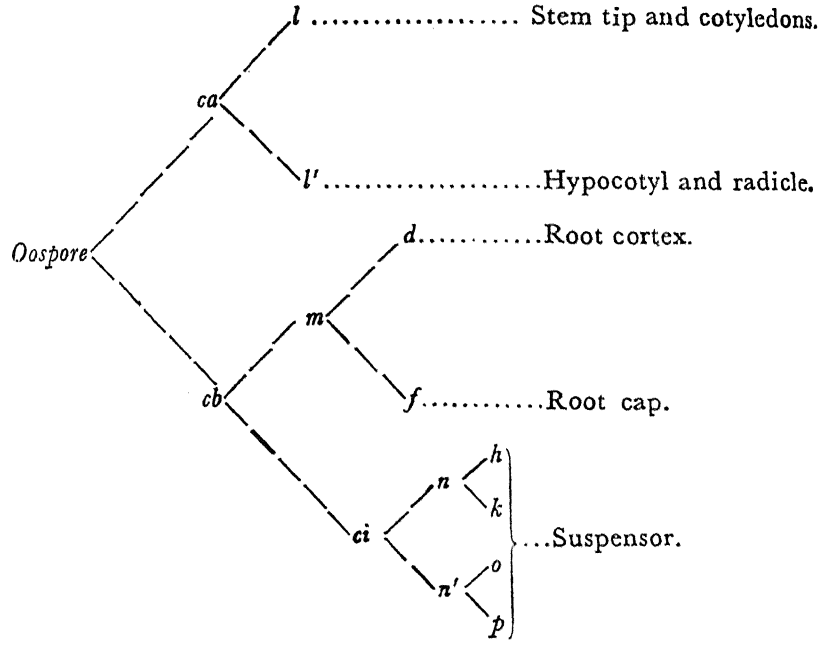
All the three species are characterized by the presence of multicellular and hypodermal archesporium (Fig. 22). In a few ovules of *Phyllanthus urinaria*, however, unicellular archesporium is noticed. One-celled archesporium is also reported in *Chrozophora obliqua* (Kapil, 1956). The archesporial cell (or cells) divides and forms a parietal cell which later on develops into the parietal tissue, and a megaspore mother cell (Figs. 23, 24, 25). The latter enlarges before meiosis. Meiosis I results in a dyad of roughly equal cells (Fig. 26). Meiosis II gives rise generally to a linear tetrad (Fig. 27). Occasionally T-shaped tetrads are also observed (Fig. 28). The three micropylar megaspores degenerate while the chalazal one functions. Its nucleus undergoes three successive divisions (Figs. 29, 30) resulting in an eight nucleate embryo sac (Fig. 31) of the Polygonum type (Maheshwari, 1950). The egg apparatus consists of an egg and two synergrids. The antipodals are three in number. The polars meet and fuse below the egg. Thus in all the three species only the normal eight nucleate embryo sac is formed. Maheshwari and Chowdry (1937) and Banerji and Dutt (1944) have reported 4-nucleate embryo sac in *Phyllanthus niruri*. This is probably due to the early degeneration of antipodals and fusion of two polar nuclei. We came across such condition in *P. urinaria* where 75–80% of the ovules showed early degeneration of the antipodals followed by the fusion of polars.

Embryo :

The embryo development follows the same pattern in all the three species of *Phyllanthus* under investigation. The fertilized egg increases in size and after a while divides transversely to form two cells, *ca* and *cb* (Figs. 36, 46, 53). The next division is also transverse and occurs in *ca* producing the cells *l* and *l'* (Figs. 37, 47)). Afterwards *cb* divides transversely giving rise to the cells *m* and *ci*. Such a sequence of division is met with in *P. urinaria* and *P. maderaspatensis* (Figs. 38, 48) but in *P. simplex* the transverse division in *cb* precedes that in *ca* (Fig. 54). Thus at the end of the second cell generation the pro-embryo becomes linear consisting of four cells designated as *l*, *l'*, *m* and *ci* (Figs. 38, 48, 55).

The first vertical wall appears in the tier *l* (Figs. 39, 49, 56). At about this time *ci* divides transversely forming the tier *n* and *n'* (Figs. 39, 49). The formation of the latter two tiers in *P. simplex*, however, takes place at a later stage than in *P. urinaria* and *P. maderaspatensis* as would be clear from the comparison of figures 39 and 49 with 56. This marks the end of the third cell generation. The pro-embryo at this stage consists of 5 or 6 cells disposed in 4 or 5 tiers. Only the upper most tier consists of two cells while the remaining ones consist of one cell each (Figs. 39, 49, 56). The second vertical division takes place in *l'* and this is soon followed by other vertical divisions in these tiers (*l* and *l'*). Simultaneously with the appearence of vertical divisions in *l* and *l'*, the tier *m* divides transversely to form *d* and *f* (Figs. 43, 50, 57) while *n* produces *h* and *k* (Figs. 41, 42, 43, 50, 57). The tier *n'* also divides transversely by this time resulting in *o* and *p* (Figs. 41, 42, 43, 50, 57).

The destination of the various tiers are as follows. The tier *l* gives rise to the two cotyledons and stem tip; *l'* produces the hypocotyl and radicle; *d* forms the root cortex while *f* produces the root cap. The tiers *n*, *n'* and their derivatives form the suspensor. This is shown below in a schematic manner.



The following is the recapitulatory table during the first 4 cell generations for the three species of *Phyllanthus*.

Ist cell generation. The pro-embryo consists of two cells disposed in two tiers.

ca = pco + pvt + phy.
cb = iec + co + s.

IInd cell generation. The pro-embryo consists of four cells disposed in four tiers.

l = pco + pvt.
l' = phy + icc.
m = iec + co.
ci = s.

IIIrd cell generation. The pro-embryo consists of six cells disposed in five tiers.

l = pco + pvt.
l' = phy + icc.
m = iec + co.
$\left.\begin{matrix} n \\ n' \end{matrix}\right\}$ = s.

IVth cell generation. The pro-embryo consists of twelve to fourteen cells disposed in eight (or six) tiers.

l = pco + pvt.
l' = phy + icc.
d = iec.
f = co.
h, k, o, p } =s.

Thus it is clear from the preceding description that the embryo development in the three species of *Phyllanthus* conforms to the Linum variation of the Solanad type of Johansen (1950) except for the fact that *iec* is derived from the tiers '*m*' unlike in the Solanad type. The embryo development in these species according to the system of Souèges (*See*, Johansen, 1950) corresponds to his Period I Series C Megarchètype IV.

This now takes us to the details about the further development of these tiers. It is stated previously that the tier *l* divides vertically forming two juxtaposed cells (Figs. 39. 40, 49, 56). They undergo one more longitudinal division producing four cells (Fig. 50), Each one of them now divides obliquely into inner cell *a* and an outer cell *b* (Figs. 41, 43, 57, 58). The former (*-a-*) which are situated adjacent to the central axis are bigger in size and quadrilateral in shape, while the latter (*-b-*) are smaller in size and triangular in shape. The outer cells and later the inner ones also divide periclinally and complete the dermatogen in the tier *l* (Figs. 51, 59).

The tier *l'* divides vertically soon after the appearence of the first vertical wall in the tier *l*. Both the resulting cells divide further vertically at right angles to the first and form four cells (Figs. 41. 42, 43, 50, 58). Next vertical divisions in them result in four outer cells and four cells placed circumaxially. The outer ones form the dermatogen and divide anticlinally only (Figs. 51, 59). The inner ones divide once more vertically and cut off the initials of plerome and periblem which by further vertical and transverse divisions produce the hypocotyl and radicle (Figs. 44, 51, 59).

The tiers *m* which is a single cell at the end of the fourth cell generation divides transversely into *d* and *f* (Figs. 42, 43, 50, 57). The upper tier *d* divides vertically twice to form four cells (Figs. 41, 42, 50, 58, 59). Soon afterwards these cells divide vertically again to cut off the dermatogen which becomes continuous with the dermatogen of the tier *l* and *l'* (Figs. 44, 51). The lower tier *f* undergoes two vertical divisions (Figs. 44, 51) and by its further differentiation contributes towards the root cap. The remaining tiers *h*, *k*, *o* and *p* derived from *n* and *n'* ultimately organize the suspensor (Figs. 40, 41, 42, 43, 50, 58, 59).

The shape of the mature embryo in *P. maderaspatensis* is shown in figure 52. In the other two species due to the bend in the cotyledons the embryo assumes a sickle shaped appearence (Figs. 45, 50). The three histogens are clearly distinguishable at this stage. The periblem as seen in longitudial section, consists of 5–6 layers in *P. simplex* and *P. urinaria* while in *P. maderaspatensis* the number varies from 5–7. The plerome consists of 3–5 layers of cells in these species. The root cap attains its maximum thickess over the extreme root tip where it is 10–12 layered in *P. simplex*, *P. urinaria* and 9–11 layers in *P. maderaspatensis*. The mature embryo shows well developed vascular supply.

Endosperm :

The endosperm which is free nuclear in the beginning ultimately becomes completely cellular. The primary endosperm nucleus divides before the fertilized egg and by the time the embryo becomes 2-celled, four free endosperm nuclei are already formed inside the embryo sac. At this stage the embryo sac slightly bends on one side at the chalazal end (Fig. 33). The free nuclear divisions in the endosperm continue till a large number of nuclei are formed inside the embryo sac (Fig 34). Only after the embryo reaches the octant stage the wall formation in the endosperm begins and by the time the embryo attains the stage shown by figure 35 the endosperm becomes completely cellular. As the embryo develops, a part of the cellular endosperm is consumed but a considerable part of it remains in the mature seed. The seeds thus are endospermic, a character that is typical of the family.

Seed coat :

As stated previously the ovules are bitegmic and both the integuments take part in the formation of testa. It is interesting to note that there is no difference in the thickness of the integuments in the species of *Phyllanthus* described in this paper. The outer integument is 2-layered while the inner one is 3-layered (Fig. 61).

The cells of the outer epidermis of the outer integument become somewhat flattened and elongated in a tangential direction in *P. urinaria* unlike in other species. The inner epidermis in *P. urinaria* gets crushed during development (Fig. 62) while in the other two species these cells enlarge and persist in the mature testa (Figs. 63, 64).

The cells of the outer epidermis of the inner integument increase in size and have band-like thickenings on their walls. The innermost layer is made up of tannin filled cells (Figs. 62, 63, 64). The middle layer in *P. urinaria* and *P. maderaspatensis* degenerates (Figs. 62, 64) during development but in *P. simplex* it persists and is filled with tannin (Fig. 63).

The mature testa in *P. maderaspatensis* and *P. simplex* is finely warty, the tubercles being arranged in regular lines both on the curved back and two faces of the trigonous seeds. In *P. urinaria* on the other hand the testa is characterized by the presence of well marked transverse furrows both on the back and the side faces.

Fruit wall :

The fruit wall, to begin with, consists of 8–10 layers of cells (Fig. 65). During development, the cells of the inner epidermis become tangentially elongated and thick walled. The cells of the inner hypodermis become very much elongated in the radial direction at right angles to the inner epidermis and their cell walls are also thickened. The third layer from inside like-wise becomes thick walled (Figs. 66, 67, 68). All the remaining layers remain parenchymatous and show granular deposits of tannins in them.

Summary :

The paper deals with the life history of three species of *Phyllanthus* viz., *P. urinaria*, *P. simplex* and *P. maderaspatensis*.

The archesporium in the anther is multicellular. The anther wall comprises the epidermis, fibrous endothecium, degenerating middle layer and secretory tapetum. The tapetal cells become bi-nucleate prior to degeneration.

Cytokinesis is by furrowing. Polyspory was noted only in *P. maderaspasensis*. The young pollen grains are arranged either in a tetrahedral or isobilateral

manner. They are spheroidal and tricolporate in *P. maderaspatensis* and tetracolporate in *P. urinaria*. In *P. simplex* the pollen grains are synrugoidorate and are provided with 20 rugoid streaks. Pollen grains are 3-celled at anthesis in *P. simplex* and *P. urinaria* while in *P. maderaspatensis* they are 2-celled.

The gynoecium is tricarpellary and trilocular. The ovules are anatropous, bitegmic and crassinucellate. The nucellus forms a nucellar beak which comes out of the micropyle and curves towards the placenta. The obturator is absent.

The female archesporium is hypodermal and multicellular. In *P. urinaria* sometimes it is unicellular. The parietal cells are cut off. The tetrad of megaspores is linear or T-shaped. The embryo sac development conforms to the polygonum type. The structure of the egg apparatus is normal. The polars fuse below the egg. The antipodals are represented by three ephemeral cells.

The nuclear endosperm becomes cellular later. The seeds are endospermic.

The embryo development conforms to the Linum variation of the Solanad type or belongs to Period I Series C Megarchetype IV.

The mature testa is derived from both the integuments. The outer epidermis of the inner integument develops characteristic band-like thickenings and forms the stony layer.

The structure of the pericarp is described.

Acknowledgements :

The authors wish to express their sincere thanks to Dr. L. B. Kajale for his guidance and helpful criticism.

References :

Banerji, I. Pollen and embryo sac of two Euphorbiaceae. *Proc. Indian Acad. Sci.*, **34** : 172–181, 1951.

——— and Dutt, M. K. The development of the female gametophyte in some members of the Euphorbiaceae. *Proc. Indian Acad. Sci.*, **20** : 51–60, 1944.

Deshpande, P. K. Contribution to the embryology of *Kirganelia reticulata* Baill. *J. Bio. Sci.*, **2** : 76–83, 1959.

Johansen, D. A. *Plant Embryology.* Waltham, Mass., U.S.A., 1950.

Johri, B. M. and Kapil, R. N. Contribution to the morphology and life history of *Acalypha indica* L. *Phytomorphology*, **3**: 137–151, 1953.

——— and Tiagi, B. Floral morphology and seed formation in *Cuscuta reflexa* Roxb. *Phytomorphology*, **2** : 162–180, 1952.

Kapil, R. N. A further contribution to the morphology and life history of *Chrozophora* Neck. *Phytomorphology*, **6**: 278–288, 1956.

Maheshwari, P. *An Introduction to the Embryology of Angiosperms.* New York, 1950.

——— and Chowdry, R. P. A note on the development of the embryo sac in *Phyllanthus niruri* L. *Curr. Sci.*, **5** : 535–536, 1937.

Mani, A. P. Development of ovule and embryo sac in *Croton bonplandianum* Baill. *Sci. Cult.*, **25** : 439–440, 1960.

Mukherjee, P. K. Studies in the embryology of *Euphorbia hypericifolia* Linn. *Bull. Bot. Soc. Univ. Sag.*, **9** : 7–18, 1957.

——— Embryology of two Euphorbiaceae. *Proc. Indian Acad. Sci.*, **53** : 217–229, 1961.

Nair, N. C. Studies on Meliaceae I. Floral morphology and embryology of *Naregamia alata* W. and A. *J. Indian bot. Soc.*, **38** : 353–366, 1959.

Prakash, R. and Chatterjee, B. Cytological study of *Solanum macranthum* Dunn. *Curr. Sci.*, **22** : 84–85, 1953.

Ram Mohan, H. Y. and Sehgal, P. P. The life history of *Justicia simplex* Don. *Phytomorphology*, **8** : 124–136, 1958.

Tandon, S. L. and Bali, P. N. Morphological and cytological studies of the diploid and naturally occurring triploid *Lantana camara* L. *Indian J. Hort.*, **12** : 1–5, 1955.

Thathachar, T. Morphological studies in the Euphorbiaceae. *Jour. Mysore Univ.*, **31** : 363–388, 1953.

Wodehouse, R. P. *Pollen Grains*. New York, 1959.

FURTHER CONTRIBUTION TO THE EMBRYOLOGY OF THE GENUS *ACALYPHA* LINN.[1]

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Introduction :

The development and structure of the female gametophyte in the genus *Acalypha* show quite interesting variations. When the different species of this genus are studied, one almost gets a series beginning from the Penaea type of embryo sac as the ancestral form which culminates into the Peperomia hispidula pattern representing the climax in the series (*See* Mukherjee, 1958). Six out of the ten species of *Acalypha* so far investigated, conform to the Penaea type of embryo sac development. These are *Acalypha brachystachya* (Kapil, 1960), *A. malabarica* (Mukherjee, 1958), *A. rhomboidea* (Landes, 1946), *A. tricolor* (Swamy and Balakrishna, 1946), *A. australis* (Tateishi, 1927) and species of *Acalypha* studied by Arnoldi (1912). Of the remaining four species, three follow a modified form of Penaea type representing the intermediate condition in the series. These are *A. ciliata* (Kajale and Murthy, 1954), *A. indica* (Johri and Kapil, 1953) and *A. fallax* (Banerji, 1949). The climax in the series is exhibited by *A. lanceolata* (Thathachar, 1952) which follows the Peperomia hispidula pattern of embryo sac development.

Like the female gametophyte the embryo development also in the genus does not conform to any one mode of development. In *A. brachystachya* (Kapil, 1960) the embryo development conforms to Euphorbia variation of the Onagrad type, while the embryo development in *A. indica* (Johri and Kapil, 1953) and *A. lanceolata* (Thathachar, 1952) corresponds to the Lotus variation under the Onagrad type of Johansen (1950). From the figures of Tateishi (1927) Johri and Kapil (1953) conclude that the embryo development in *A. australis* also follows the same course as in *A. indica* (Johri and Kapil, 1953), but according to Johansen (1950) it conforms to Euphorbia variation of the Onagrad type. The present investigation, therefore, has mainly been undertaken in the hope of finding out the trends of variation in the embryo development of the different species of *Acalypha*. Two local species, therefore, have been selected and described in the present paper. While sectioning the material the different stages in the development of anther, pollen grains, seed coat and fruit wall were available. Consequently these have also been incorporated in the present communication.

Microsporogenesis and Male gametophyte :

In both the species the anthers are monothecous as in *A. brachystachya* (Kapil, 1960) and *A. indica* (Johri and Kapil, 1953). Consequently the archesporium arises at two places in an young anther. It consists of 2 or 3 cells in transverse (Figs. 1, 15) and 10 to 15 cells in longitudinal section. It divides periclinally into a primary parietal layer on the outer side and a primary sporogenous layer on the inner side. The former during subsequent development forms three layers (Figs. 2, 3, 16, 17). The one below the epiderms develops into the fibrous endothecium in the

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mature anther (Figs. 6, 20). The middle one begins to degenerate after meiosis II (Figs. 4, 5, 18–20) but the degenerating remains of its cells are seen to persist at places till the pollen grains become two uncleate (Figs. 6, 20). The innermost layer develops into tapetum. The anther wall including the epidermis thus comprises four layers as in *A. fallax* (Banerji, 1949), *A. lanceolata* (Thathachar, 1952) *A. indica* (Johri and Kapil, 1953) and *A. brachystachya* (Kapil, 1960). During development the cells of the epidermis except two rows become very much flattened and as the anther reaches maturity they slowly degenerate (Figs. 4, 5, 18--20). Their remains, however, are always seen attached to the fibrous endothecium on its outer side (Figs. 6, 20), unlike in *A. indica* in which according to Johri and Kapil (1953) they become flattened and persists in the mature anther without undergoing degeneration. The degeneration of the epidermal layer in *A. ciliata* and *A. malabarica* starts before the commencement of meiosis in the pollen mother cells. The two epidermal rows of cells along the outer margin of the anther in both these species become conspicuous by their large size and thickened cell walls (Figs. 5, 6, 19, 20). Correlated with this change, the cells of the fibrous endothecium situated below them remain poorly developed. This constitutes the dehiscence mechanism in the anther of these species as in *A. indica* (Johri and Kapil, 1953). This is probably a character of the genus.

The nucleus of the tapetal cells, during meiosis of the pollen mother cells divide mitotically once and the cells become bi-nucleate. In this condition the tapetal cells persist till the end and degenerate in situ. Thus the tapetum is of the secretory type as in *A. fallax* (Banerji, 1949), *A. lanceolata* (Thathachar, 1952) and *A. brachystachya* (Kapil, 1960). In *A. indica* according to Johri and Kapil (1953) the tapetum forms a true periplasmodium. These authors have further stated "such a difference between species of the same genus is not likely and the species *A. fallax* (=*A. lanceolata*) needs to be re-examined". In view of this statement it was thought necessary to study the behavior of the tepetum critically in the two species under investigation. Some material of *A. indica* for this purpose was also cut and examined. My observations do not confirm the findings of Johri and Kapil (1953). The correct situation in this regard is stated below.

It is already pointed out that the tapetal cells which are uni-nucleate in the beginning become bi-nucleate later and slightly increase in size. After the close of meiosis, when the pollen grains are formed, an interesting change takes place in the inner tangential walls of the tapetal cells. These walls gradually become perforated and when seen in section present a finely beaded appearence (Figs. 5, 6, 19, 20). Such a change in the cell wall is seen not only in *A. ciliata* and *A. malabarica* but is also observed in *A. indica*, the material of which was specially sectioned and studied from this point of view. As the pollen grains develop, a chemical substance secreted by the protoplasm of the tapetal cells flows through these fine perforations in the anther loculus in between the young pollen grains forming a continuous mass with the mucilage surrounding the latter. This looks very much like the true periplasmodium and has probably led Johri and Kapil (1953) to conclude that periplasmodium is formed in *A. indica*. The secreted product takes the same stain as the mucilage in slides stained with haematoxylin and counterstained with erythrosin suggesting that these two substances may be chemically alike. During all this time the nuclei do not come out of the tapetal cells as is seen when true periplasmodium is formed but remain inside the cells and degenerate in situ together with the cytoplasm in course of time (Figs. 5, 6, 19, 20). It is thus clear from the preceding description that there is no formation of true periplasmodium in any species of *Acalypha* so far investigated.

The pollen mother cells as usual undergo two meiotic divisions. During this time the cytoplasm in each cell recedes from the cell wall and become enveloped in a mucilaginous sheath (Figs. 7, 21). The division of the pollen mother cells is simultaneous. The resulting nuclei are arranged either in a tetrahedral or an isobilateral manner (Figs. 8, 9, 22). Cytokinesis is affected by centripetal furrows (Figs. 7, 21). These appear at the periphery and progressing inward along with mucilaginous sheath meet in the centre to bring about the separation of young pollen grains. As development proceeds the mucilaginous sheath and the cell walls disappear and the pollen grains are liberated free in the anther loculus.

The young pollen grain is rich in cytoplasm and it soon acquires intine and exine. As it develops, a big vacuole appears in centre pushing the nucleus on one side (Figs. 10, 23). Here the nucleus divides forming a small generative cell and a comparatively big tube cell (Figs. 11, 24). The former divides to form two male gametes (Figs. 12, 13). The vegetative nucleus presents a lobed appearence as in *A. indica* (Johri and Kapil, 1953). At the time of shedding the pollen grains are 3-celled in *A. malabarica* (Figs. 12, 13). The mature pollen grains show the presence of starch in them. The pollen grains in *A. ciliata* are probably shed when they are 2-celled (Fig. 24).

The intine is a thin membrane and it protrudes out of the germ pores. The exine is smooth and striated. It has three germ pores (Figs. 14, 25) as in *A. indica* (Johri and Kapil, 1953). While this is the general condition a few cases were noticed in *A. malabarica* in whlch pollen grains had four germ pores (Fig. 13). Thus the genus is characterised by the presence of triporate pollen grains though occasionally tetraporate grains are met with.

Fertilization :

This is studied only in *A. malabarica.* The fertilization in this species is porogamous. The two lateral and one chalazal egg apparatus start degenrating before the pollen tube enters the embryo sac. The cause of this degeneration is not known. However, the two synergids at the micropylar end begin to degenerate as the pollen tube enters the embryo sac (Fig. 26). The tube reaches up to the base of the egg and discharges the contents. One of the male gametes fuses with the tetraploid secondary nucleus which becomes pentaploid.

Endosperm :

The primary endosperm nucleus divides earlier than the zygote as in *A. brachystachya* (Kapil, 1960) and *A. indica* (Johri and Kapil, 1953). This was clearly observed in *A. malabarica* (Fig. 49). Probably a similar condition exists in *A. ciliata* also. The free nuclear divisions in the endosperm continue for some time and the resulting nuclei become placed at the periphery surrounding a central vacuole (Figs. 50, 51, 53). During the first few free nuclear divisions the nuclei are generally seen aggregated on the chalazal side (Figs. 49, 50) though sometimes they become aggregated near about the developing embryo. But later on, however, the nuclei are seen evenly distributed in the peripheral layer of the cytoplasm.

The wall formation in the endosperm is almost simultaneous and commences from the periphery towards the centre. In *A. ciliata* it was observed that some of the nuclei at the periphery become enclosed by cell walls while others continue to remain in a free nuclear manner for a short while (Fig. 54). But the whole process takes place so quickly that it appears as if the wall formation in endosperm is simultaneous. This happens at about the time when embryo attains the stage represented by figures 52, 54 and by the time the two cotyledons are well

differentiated the entire embryo sac become filled with cellular endosperm (Fig. 65). The endosperm increases in bulk crushing the nucellar cells. At the chalazal side, however, small part of the nucellus persists as perisperm devoid of any food material or chemical deposits (Fig. 65). Some of the nucellar cells near the vascular strand (*See*, Mukherjee, 1958) become thick walled and get filled with tannin acting as a poorly developed hypostase (Fig. 65). A part of the endosperm is consumed by the growing embryo but a major part of it persists in the mature seed. The seeds therefore are endospermic as in *A. indica* (Johri and Kapil, 1953). In the mature seed the peripheral cells of the endosperm are rectangular in shape when seen in section while others appear polygonal. The cells are rich in oil and starch deposits and the nuclei have several nucleoli in them.

Embryo :

The oospore enlarges in size and becomes vacuolated. During enlargement it generally retains its flask-shaped appearence in *A. malabarica* but in *A. ciliata* it usually presents no definite shape (Fig. 39). The first division of the fertilized egg in both the species is transverse resulting in a basal cell *cb* and an apical cell *ca* (Figs. 27, 40). The former which is cut off on the micropylar side is generally bigger and more vacuolated than *ca* (Fig. 27). Though this is usual condition, in *A. ciliata* these cells sometimes are of the same size and occasionally the cell *cb* is even smaller than the cell *ca* (Fig. 40).

The first division is soon followed by the second and is initiated in the cell *cb*. In *A. malabarica* it is generally transverse forming the cells *m* and *ci* (Fig. 30) but occasionally it is oblique or nearly vertical and consequently there is no formation of the tiers *m* and *ci* (Fig. 28).

In *A. ciliata* on the other hand the second division in *cb* is either vertical or oblique (Figs. 41, 42, 43) and there is no formation of the tiers *m* and *ci* in this species. A similar situation is reported by Thathachar (1952) in *A. lanceolata*. Rarely, however, it is transverse simulating the differentiation of the tier *m* (Fig. 44) but it takes no part in the development of the embryo proper. It is also observed that the two cells derived from *cb* do not divide in any definite order during subsequent development indicating very clearly that the tiers *m* and *ci* are absent in *A. ciliata*.

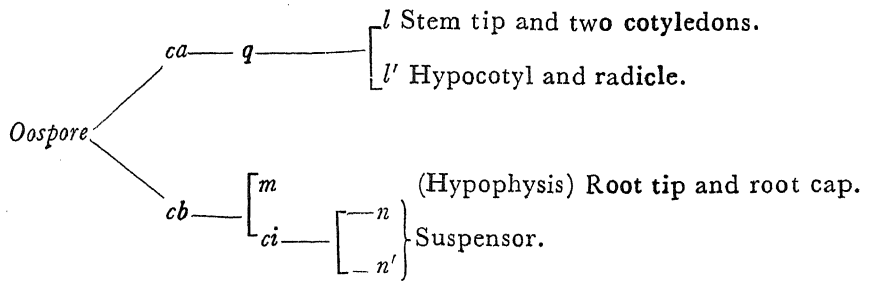
The tier *ci* in *A. malabarica* sometimes divides transversely to form *n* and *n'* (Fig. 29). Generally it does not form *n* and *n'* but instead undergoes oblique or vertical divisions (Figs. 30, 31) behaving in a manner corresponding to the tier *cb* in *A. ciliata* (Fig. 42) or *A. indica* (Johri and Kapil, 1953).

The apical tier *ca* divides vertically into two cells together designated as *q* (Figs. 28, 41, 42). This vertical division in *A. malabarica* takes place after the first division is completed in *cb* and results in the formation of a T-shaped pro-embryo consisting generally of four cells disposed in three tiers. The apical tier *q* consists of two cells while the remaining tiers, *m* and *ci*, consists of one cell each. Occasionally the pro-embryo consists of five cells if the cell *ci* divides into *n* and *n'* (Fig. 29). In *A. ciliata* the pro-embryo generally consists of four cells disposed in two tiers each having two cells (Figs. 41, 42).

The two cells (*q*) resulting from the first vertical division of the apical cell divide once again vertically forming four cells (Figs. 31, 42, 43, 45). Each one of them now divides transversely forming an octant of two tiers *l* and *l'* (Figs. 32, 44).

The origin of the various parts of the mature embryo from the different tiers of the pro-embryo and their embryonic formulae for the three successive generations are described below :

A. malabarica.



Ist cell generation. The pro-embryo consists of 2 cells disposed in two tiers and their destinations are as follows :

$$ca = pco + pvt + phy + icc$$
$$cb = iec + co + s$$

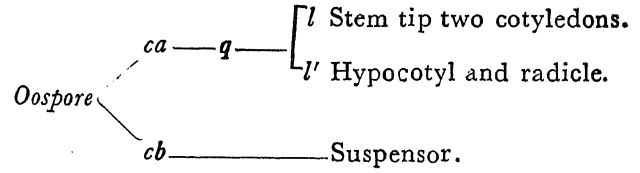
IInd cell generation. The pro-embryo consists generally of 3 cells arranged in three tiers of one cell each and their destinations are as follows :

$$ca = pco + pvt + phy + icc$$
$$m = iec + co$$
$$ci = s$$

IIIrd cell generation. The pro-embryo consists of 5 cells disposed generally in 4 tiers. The apical tier (*q*) consists of two cells, the penultimate one (*m*) consists of a single cell, while the remaining two (*n* and *n'*) are composed of one cell each. If, however, *ci* divides obliquely the pro-embryo consists of 3 tiers. The two end tiers (*q* and *ci*) consists of two cells each while the middle one is composed of a single cell. The destinations are as follows :

$$q = pco + pvt + phy + icc$$
$$m = iec + co$$
$$\left.\begin{matrix} n \\ n' \end{matrix}\right\} = s$$

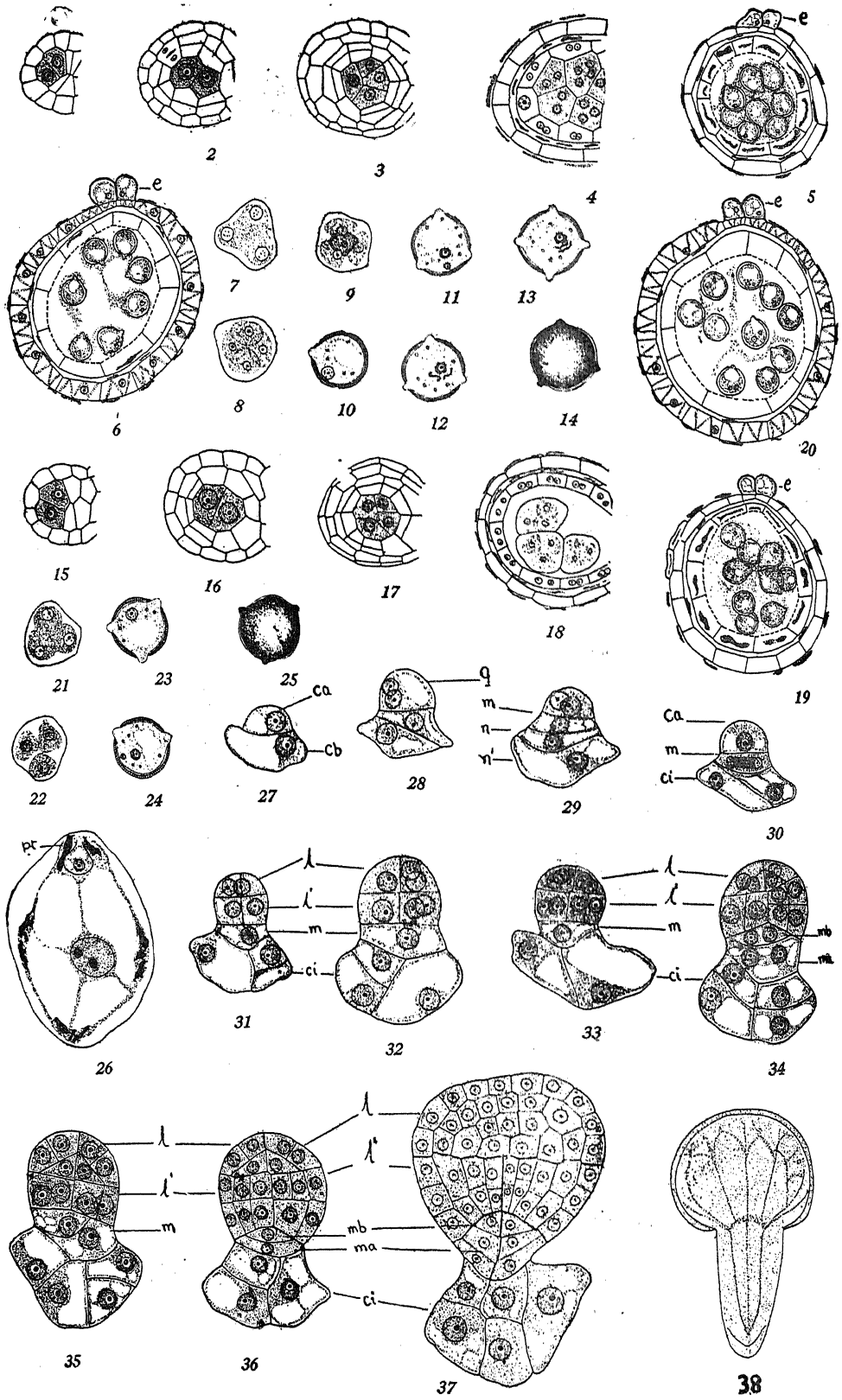
A. ciliata.



Ist cell generation. The pro-embryo consists of 2 cells disposed in two tiers and their destination are as follows :

$$ca = pco + pvt + phy + icc + iec + co$$
$$cb = s$$

IInd cell generation. The pro-embryo consists of 4 cells arranged generally in two tiers (*q* and *cb*). Their destinations are the same as in the Ist cell generation.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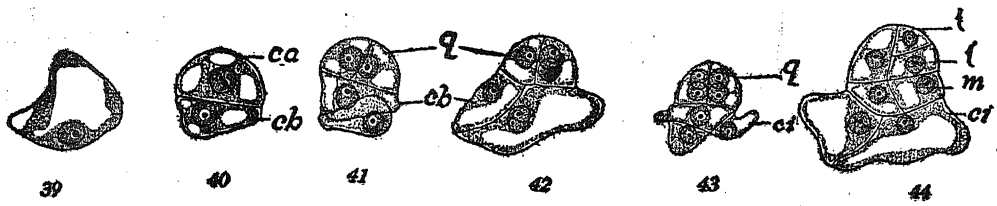

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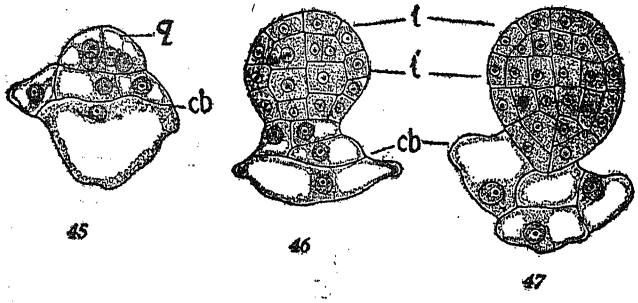

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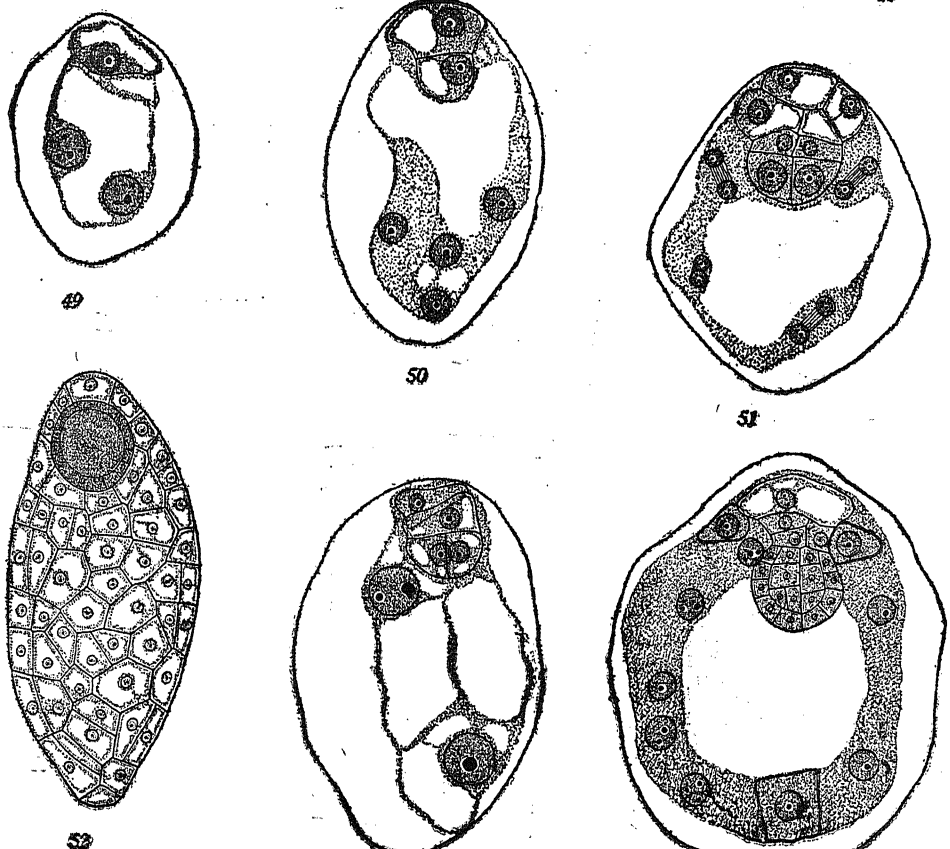

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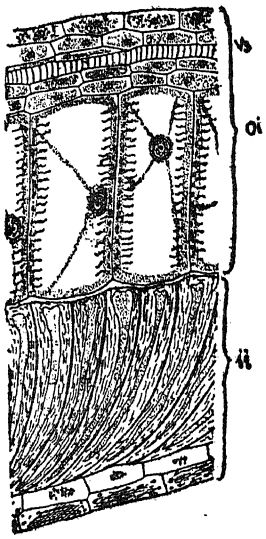

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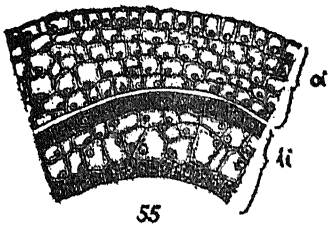

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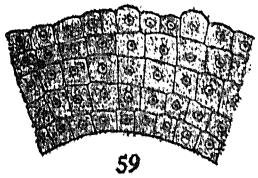

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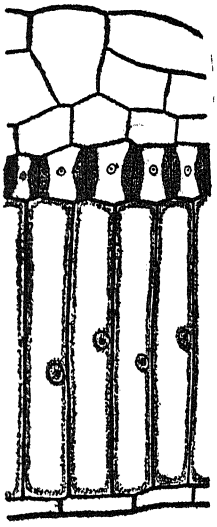

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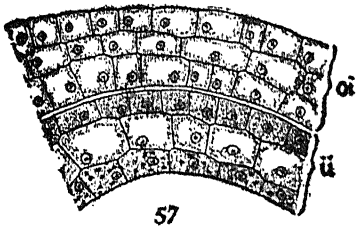

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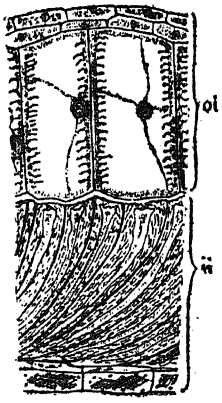

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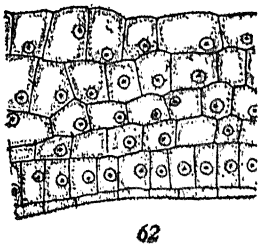

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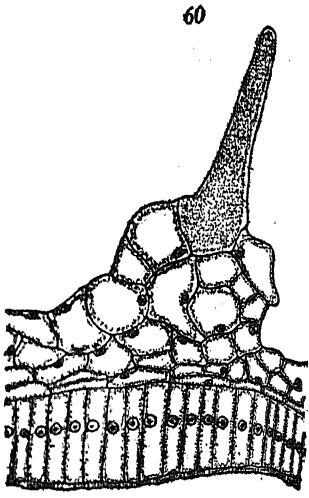

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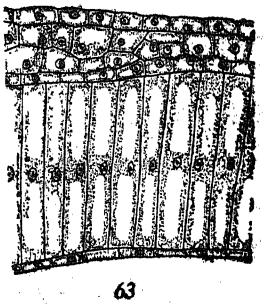

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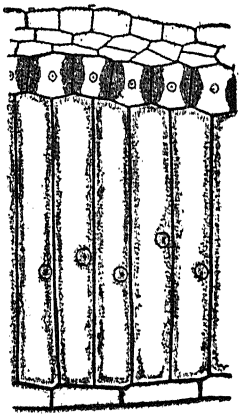

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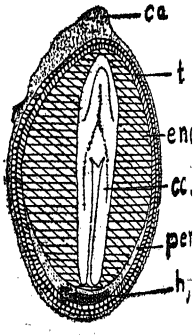

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EXPLANATION OF FIGURES

Plate 1

Figures 1-14 and 26-38. *Acalypha malabarica.* Fig. 1. T.S. anther lobe showing hypodermal multicellular archesporium. X600. Figs. 2, 3. The same at a later stage. X600. Fig. 4. The same showing degener ating epidermis, degenerating middle layer and binucleate tapetum X600. Fig. 5. The same showing uni-nucleate pollen grains. Note the degenerating tapetum and the perforations on the inner tangential walls of the tapetal cells X600. Fig. 6. T.S. anther lobe showing 2-nucleate pollen grains. Note the presence of two enlarged and thick walled epidermal cell (*e*), fibrous endothecium and the degenerating middle layer. In figures 5 and 6 the thinly shaded portion represents the mucilage X600. Fig. 7. Beginning of cytokinesis X850. Figs. 8, 9. Isobilateral and tetrahedral arrangement of young pollen grains. X850. Figs. 10-13. Pollen grains showing development of the male gametophyte. Note the tetraporate pollen grain in Fig. 13 X850. Fig. 14. Triporate pollen grain X850. Fig. 26. L.S. embryo sac showing micropylar egg with a part of the pollen tube (*pt*) and three degenerating egg apparatuses X600. Figs. 27-37. Stages in the development of embryo X600. Fig. 38. Mature embryo X30.

Figures 15-24. *Acalypha ciliata.* Fig. 15. T.S. anther lobe showing hypodermal multicelluar archseporium X600. Figs. 16, 17. The same at a later stage X600. Fig. 18. The same showing degenetraing epidermis, degenerating middle layer and binucleate tapetum X600. Fig. 19. The same showing uninucleate pollen grains. Note the degenerating tapetum and perforations on the inner tangential walls of the tapetal cells X600. Fig. 20. T.S. anther lobe showing 2-nucleate pollen grains. Note the presence of enlarged and thick walled epidermal cells (*e*), fibrous endothecium and the degenerating middle layer. In figures 19 and 20 the thinly shaded porton represents the mucilage X600. Fig. 21. Beginning of cytokinesis X850. Fig. 22. Tetrahedral arrangement of young pollen grains X850. Figs. 23, 24. Pollen grains showing development of male gametophyte X850. Fig. 25. Triporate pollen grain X850.

Plate 2

Figures 39-48 ; 53, 54. *Acalypha ciliata.* Fig. 39. Zygote X600. Figs. 40-48. Stages in the development of embryo X600. Fig. 53. Embryo sac showing 2 free endosperm nuclei and 4-celled pro-embryo X600. Fig. 54. The same at a later stage. Note the formation of cell walls round ome of the endosperm nuclei at the chalazal and micropylar X430.

Figures 49-52. *Acalypha malabarica.* Fig. 49. Embryo sac with zygote and 2 free endosperm nuclei X600. Figs. 50, 51. The same as above showing development of pro-embryo and free nuclear endosperm X600. Fig. 52. L.S. embryo sac showing cellular endosperm. The darkly shaded part represents the embryo X250.

Plate 3

Figures 55, 56 ; 59-61, 65. *Acalypha malabarica.* Fig. 55. L.S. part of the integuments X300. Fig. 56. L.S. part of mature testa. Note the vascular supply (*vs*) in the outer integument X250. Fig. 59. T.S. part of the young ovary wall X600. Fig. 60. L. S. part of mature pericarp X600. Fig. 61. T.S. part of pericarp showing trichome on multicellular base X600. Fig. 65. L.S. mature seed X250.

Figures 57, 58 ; 62-64. *Acalypha ciliata.* Fig. 57. L.S. part of the integuments X300. Fig. 58. L.S. part of mature testa X600. Fig. 62. T.S. part of the ovary wall X600. Fig. 63. Part of ovary wall at slighly later stage X600. Fig. 64. L.S. part of mature pericarp. For details see taxt.

Abbreviations—

e—Degenerating epidermis.
ca—Caruncle.
cot—Cotylendons.
end—Endosperm.
hy—Hypostase.
ii—Inner integument.
oi—Outer integument.
per—Perisperm.
pt—Pollen tube.
t—Testa.
vs—Vascular supply.

IIIrd cell generation.—The pro-embryo consists of 6 to 8 cells arranged in two tiers. Their destinations are the same as in IInd cell generation.

It is interesting to note that in *A. ciliata* during subsequeut development of the embryo there is no change in the destinations of the two tiers which are produced as a result of the first transverse division of the egg. This is probably a distinguishing feature of the embryo development in this species. It is also clear from the preceding description that there is no formation of the hypophysis in *A. ciliata* and therefore the embryo development in this species in the main, conforms to the Lotus variation under the Onagrad type (Johansen, 1950) as in *A. indica* (Johri and Kapil, 1953) and *A. lanceolata* (Thathachar, 1952).

In *A. malabarica* on the other hand the cell *m* which functions as hypophysis is generally present and its first division is typically curved. It thus conforms to the Onagrad variation under the same type (Johansen, 1950).

Further details about the development of the embryo are discussed in the following paragraphs :

After the octant stage is reached the cells of the tier *l'* in *A. malabarica* divide periclinally demarcating the dermatogen (Fig. 33). It is later completed in the tier *l*. These stages were not available in *A. ciliata*. After the dermatogen is completed, the tier *l'* in both the species divides first by transverse walls (Figs. 34, 46). Later on it divides both vertically and transversely giving rise to the hypocotyl and radicle in *A. malabarica* (Fig. 36). In *A. ciliata*. however, it contributes to the root cap also in addition to the hypocotyl and radicle (Fig. 47). This is described in detail shortly afterwards.

The cells of the tier *l* later on differentiate into two cotyledons and stem tip (Figs. 34–37, 46, 47).

The tier *m* functions as the hypophysis. It is formed only in *A. malabarica*. To begin with, it consists of a single cell. As development proceeds, it generally divides by curved wall, the ends of which meet first transverse wall that separates the tiers *ca* and *cb* thus forming the cells *ma* and *mb* (Figs. 34, 36). Though this is the general condition, in one exceptional case one of the ends of the curved wall was seen to meet the lateral wall (Fig. 35). In a few exceptional cases it was also observed that the cell *m* divided vertically first by a straight wall instead of forming a curved wall so typical of the Onagrad type (Fig. 30). Details in this connection could not however be studied.

It is already stated that the organization of the curved wall in the tier *m* results in two cells *ma* and *mb* (Figs. 34, 36). The lower cell *ma* looks like an inverted watch glass while the upper one *mb* having curved wall looks like an inverted cone with its apex towards the embryonal mass. Thus the development of the hypophysis in *A. malabarica* is very much similar to what is described in *Oenothera biennis* (Souèges, 1920) or in the Onagrad type in general (Johansen, 1950).

Each one of the two cells, *ma* and *mb*, divide twice by vertical walls at right angles to each other forming four cells. Later, the cells of the tier *ma* divide periclinally and anticlinally forming the root cap while those of the tier *mb* contribute to the periblem and plerome of the root tip (Fig. 37).

It is already stated that the tier *m* is not formed in *A. ciliata*. The root cap and the root tip is, therefore, organized by the tier *l'*. After the dermatogen is demarcated the cells of this tier divide transversly. Those cut off on the micropylar side contribute to the root cap and root tip while those on the side of the embryonal mass produce the hypocotyl and radicle (Figs. 46, 47).

Except the cell *m* the remaining cells derived from the cell *cb* in *A. malabarica* give rise to the suspensor. In *A. ciliata* there is generally no differentiation of the cell *m* and the cell *cb* and its derivatives form the suspensor. Even in those cases where *m* is differentiated, it takes no part in the formation of embryo proper but it (*m*) contributes towards the suspensor only.

The suspensor in both the species consists of large and vacuolated cells (Figs. 37, 47, 48) as in *A. lanceolata* (Thathachar, 1952) and *A. indica* (Johri and Kapil, 1953). This type of suspensor appears to be typical of the genus differing from species to species only in the number of cells.

The mature embryo is typically dicotyledonous (Fig. 65). The cotyledons are flat, broad and cordate (Fig. 38). The maximum thickness of the root cap is 7–8 layers which gradually diminishes to a single layer towards the cotyledon side. The plerome consists of 3–4 layers while the periblem comprises about 5–6 layers. The vascular tissue divides and redivides in the cotyledons. The various parts of the embryo show the deposit of oil globules in their cells.

Testa :

The ovules are bitegmic and both the integuments take part in the formation of testa. At about fertilization the inner integument in *A. malabarica* consists of 5–6 layers on the chalazal side, 2–3 layers on the micropylar side and about 4 layers in the middle region (Fig. 55). Like the inner integument the outer one also consists of 5–6 layers (Fig. 55) on the chalazal side but it becomes thicker towards the micropylar end and consists of about 10 layers of cells in this part. In *A. ciliata* the inner integument comprises 3–4 layers (Fig. 57) on the chalazal, and 2–3 layers on the micropylar side while the outer one consists of 3–4 and 8–10 layers of cells in these regions respectively.

During development, several changes are noticed in the cells of the integuments. The cells of the inner epidermis of the integument become broad and elongated. Their radial walls show fibrous thickening (Figs. 56, 58) as in *A. indica* (Johri and Kapil, 1953). The cells of the outer epidermis remain parenchymatous and show the presence of yellow granules in them in slides stained with haematoxylin (Figs. 56, 58). The intermediate layers also remain parenchymatous and do not undergo any marked change during development.

The cells of the outer epidermis of inner integument develop highly sclerosed walls with numerous pit canals. They are obliquely oriented and are somewhat sickle shaped as shown in figures 56 and 58. Their base is 5-6 sided and is adjacent to the outer integument while their tapering ends face inwards (Figs. 56, 58). This forms the brittle stony layer of the mature seed as reported by Netolitzky (1926), Landes (1946), Johri and Kapil (1953), Kajale (1954) and Mukherjee (1960) in the different species studied by these authors. The cells of the inner epidermis in both the species become filled with granular deposits and their walls develop band like thickenings (Figs. 56, 58). The intermediate layers become flattened and some of them especially on the chalazal side are crushed during development.

Caruncle :

After fertilization the inner integument grows and closes over the nucellus. The outer integument enlarges and crushes the obturator. The caruncle develops from the micropylar part of the outer integument. The cells in this part divide repeatedly forming a conspicuous mass of loose cells which ultimately forms a caruncle of the seed. The caruncle is grooved lengthwise. Its cells, in general, are cuticularized and the cuticularization becomes more pronounced in the

epidermal cells. Here also the deposition of cuticle is more conspicuous on the outer tangential walls than on the inner ones. The development of the caruncle in the two species under investigation agrees in general with that in *A. rhomboidea* (Landes, 1946) and *A. indica* (Johri and Kapil, 1953). The presence of caruncle is reported in several species of the Euphorbiaceae. Schweiger (1905) noted its occurrence in species of the genus *Euphorbia* studied by him. According to Landes (1946) caruncle occurs in *A. rhomboidea* and six species of *Euphorbia*. Thathachar (1952) also says that caruncle develops from the outer integument.

Fruit wall :

The ovary wall at the megaspore mother cell stage in both species consists of 5-6 layers of parenchymatous cells rich in cytoplasm (Figs. 59, 62). Out of them, the cells of the three inner layers become ultimately sclerosed and undergo a marked change in shape and size during development while the outer three layers do not undergo any marked change and remain parenchymatous till end. The cells of the inner epidermis become flattened and tangentially elongated (Figs. 60-63). Those of the inner hypodermis are very much enlarged in size and become radially elongated at right angles to the epidermal cells (Figs. 60, 61-63). The cells forming a layer immediately on the outer side of inner hypodermis increase in size and their radial walls acquire a lenticular thickening when seen in section (Figs. 60, 64). The remaining two or three outer layers form a zone of parenchymatous cells (Fig. 61).

Trichomes are present on the pericarp of *A. malabarica*. These are mounted on a broad, conical multicellular base (Fig. 61). A few multicellular glands similarly mounted are present here and there in between the trichomes. The glands and trichomes are restricted mostly to the upper half of the fruit.

In *A. ciliata* glands are absent on the pericarp but a few trichomes are seen on the fruit which almost looks glabrous.

Summary :

The paper gives an account of the development of the anther, pollen grain, endosperm, embryo, seed coat and fruit wall of *Acalypha malabarica* and *A. ciliata*.

The anthers are monothecous. The archesporium is multicellular and hypodermal. Anther wall comprises the epidermis, fibrous endothecium, degenerating middle layer and the tapetum. Except the two rows of cells the remaining part of the epidermis degenerates during development. The tapetal cells become bi-nucleate and degenerate in situ forming a secretory type of tapetum. Johri and Kapil (1953) have stated that there is a formation of periplasmodium in *A. indica*. This is contradicted and the correct situation in this regard is described in the text. The division of the pollen mother cells is simultaneous. Cytokinesis takes place by means of furrows. The arrangement of the young microspores is either tetrahedral or isobilateral. Pollen grains are smooth and triporate. Rarely they are tetraporate. At anthesis they are 3-celled in *A. malabarica* and 2-celled in *A. ciliata*.

Fertilization is porogamous.

Primary endosperm nucleus divides earlier than the zygote. The endosperm is free nuclear in the beginning but later becomes completely cellular. The wall formation in endosperm begins almost simultaneously at the periphery and progresses towards the centre. The cells of the endosperm are rich in oil and starch.

The first division of the zygote is transverse. The embryo development in *A. ciliata* conforms to the Lotus variation under the Onagrad pattern of Johansen

(1950) while that of *A. malabarica* follows the Onagrad variation under the same type. Mature embryo is straight and dicotyledonous.

The testa develops from both the integuments. The cells of the outer integument remain mostly parenchymatous and constitute a soft part of the testa while those of the inner integument form a hard part of the testa. The caruncle is formed from the micropylar part of the outer integument.

The seeds are endospermic. The mature pericarp comprises 5–6 layers. The three inner layers consist of thick walled cells while the remaining ones constitute a zone of parenchymatous cells. Trichomes mounted on broad multicellular conical base are present on the pericarp of *A. malabarica*, mostly on its upper half. Likewise multicellular glands are also seen here and there in between the trichomes.

Acknowledgements :

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References :

Arnoldi, W. Zur Embryologie einiger Euphorbiaceen. *Trans. Mus. Bot. Acad. St.* Petersbourgh, **9** : 134–154, 1912.

Banerji, I. A contribution to the life history of *Acalypha fallax*, Muell. *Arg. Bull. Bot. Soc. Bengal*, **3** : 29–32, 1949.

Johansen, D. A. *Plant Embryology*. Waltham, Mass., U.S.A., 1950.

Johri, B. M. and Kapil, R. N. Contribution to the embryology and life history of *Acalypha indica* L. *Phytomorphology*, **3** : 137–151, 1953.

Kajale, L. B. Fertilization and the development of embryo and seed in *Euphorbia hirta* Linn. *Proc. nat. Inst. Sci. India*, **20** : 353–360, 1954.

——— and Murthy, K. S. N. The embryo sac of *Acalypha ciliata* Forsk. *J. Indian bot. Soc.* **33** : 417–422, 1954.

Kapil, R. N. Embryology of *Acalypha* Linn. *Phytomorphology*, **10** : 174–184, 1960.

Landes, M. Seed development in *Acalypha rhomboidea* and some other Euphorbiaceae. *American. J. Bot.* **33** : 562–568, 1946.

Mukherjee, P. K. The female gametophyte of *Acalypha malabarica* Muell. with a brief discussion on the Penaea type of embryo sac. *J. Indian bot. Soc.* **37** : 504–508, 1958.

——— Embryology of two Euphorbiaceae. *Proc. Indian Acad. Sci.* **53** : 217–229, 1960.

Netolitzky, F. "*Anatomie der Angiospermen–Samen*". Berlin, 1926.

*Schweiger, J. Beiträge zur Kenntnis der Samenentwicklung der Euphorbiaceen. *Flora.* **94** : 339–379, 1905.

Souèges, R. Embryogénie des Oenothéracées Développment de l'embryon chez *l'Oenothera biennis. C. R. Acad. Sci. Paris.* **170** : 946–949, 1920.

Swamy, B. G. L. and Balakrishna, B. P. Female, gametophyte of *Acalypha tricolor. J. Indian bot. Soc.* **25** : 67–69, 1946.

Tateishi, S. On the development of the embryo sac and fertilization of *Acalypha australis* L. *Bot. Mag. Tokyo*, **41** : 477–485, 1927.

Thathachar, T. Morphological studies in the Euphorbiaceae. I. *Acalypha lanceolata* Willd. *Phytomorphology*, **2** : 197–201, 1952.

*Not seen in original.

THE INFLUENCE OF MOLYBDENUM ON THE GROWTH OF ROOT AND SHOOT OF *CAJANUS CAJAN*

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Introduction

The precise function of molybdenum in plant nutrition still remains a mystery in many aspects of plant life. Moly, in traces, is essential for the normal growth of plants. The lime-loving plants, as a rule, require more molybdenum than the acid-loving ones (Cripps, 1956). This micro element is known to be associated with nitrogen fixation by both the symbiotic and free-living soil organisms (Purvis, 1955). It worked as a catalyst in nitrate reduction or nitrate utilization in plants (Russell, 1950 ; Rubins, 1955 : Mulder *et al*, 1959). Liming of soils was believed to be primarily linked with the release of molybdenum due to its solubilizing effect on soil molybdenum (Kline, 1954 ; Bear, 1955).

Molybdenum affected the growth and colour of leaves (Arnon, 1938 ; Brenchley and Warington, 1942), changed the habit of growth from the erect to the trailing type (Sheffild, 1943), increased dry matter production (Lal and Rao, 1954) and bettered the development of plant organs (Subba Rao, 1951). The differential response to molybdenum depended on its content of the seed (Meagher and associates 1952 ; Hewitt *et al*, 1952 and Johnson and Colleagues, 1952), on the supply of nitrogen (Anderson and Spencer, 1950), liming (Cripps, 1956), extent of nodulation of the legume (Anderson and Moye, 1952 ; Kline, 1954) besides other factors that have not received adequate attention.

The literature available is particularly lacking on the comparative effect of molybdenum on the growth of light-loving and light-avoiding parts of the plant. This aspect has been studied under various levels of molybdenum supply with *Cajanus cajan* seedling.

Materials and Methods

Seeds of *Cajanus cajan* (Type 1) were allowed to germinate and after the emergence of the radicle seedlings were transferred to acid washed sand (Hewitt, 1947) in polythene container of 740 gm capacity. Plants received diffused day light throughout the period of experimentation.

The effect of Mo supply was evaluated with 4 concentrations *viz.* (1) complete nutrient with no molybdenum supply (–Mo) ; (2) Complete nutrient (Arnon, 1938) with 0·01 ppm of Mo (Mon) ; (3) 1·25 ppm of molybdenum (Moa), in addition to treatment designated in 1 above ; and (4) 2·5 ppm of molybdenum (Mob), in addition to treatment designated in (1) above.

Molybdenum deficient solution that formed the basic supply of nutrients was added six times during the period of study. Distilled water in the molybdenum free series and the requisite amount of molybdenum in other series were added on alternate days.

Treatment effect was noted four times, every 7 days after the plants had attained the age of 20 days. Both the qualitative as well as quantitative expression of growth *viz.*, number of roots, length of roots, height of stem, and fresh as

well as dry weight of both the roots and shoots were recorded. Average of data from twelve plants have been reported in the tables. The light-loving and light-avoiding parts of the plant were analysed with respect to sugars and amino acids chromatographically.

The extraction procedure followed for the chromatographic assay of sugars was the one recommended by Steward *et al* (1954). Sugars were separated and identified by circular paper chromatographic technique (Ranjan *et al*, 1955). Chromatograms were developed by spraying the aniline-diphenylamine phosphate reagent (Buchan and Savage, 1952) and then drying the chromatograms for ten minutes at 80°C. Quantitative estimation of individual sugars was done by elution of the chromatograms and estimation by Somogyi's method (1945).

Consdon's (1944) two dimensional chramatographic technique was followed for the detection of amino acids. The extract was spotted 3 cm. away from each of the sides of the chromatography paper. Fowden's (1954) modification of Partridge's solvent, phenol saturated with 0·5% (V/V) NH_4OH solution was used as first solvent. *n*-butanol, acetic acid and water combination in the ratio of 4 : 1 : 5 was used as second solvent for the other side and allowed to dry. Spots were located by spraying with ninhydrin 0·1% (W/V) in normal butanol. The dry chromatograms were kept in an atmosphere of 85°C for about half an hour and later exposed to normal conditions for 30 minutes.

Average values have been presented in the table as judged on the basis of area as well as intensity of the spots.

EXPERIMENTAL FINDINGS

Qualitative Expression of Growth

Branching behaviour : Marked difference in branching behaviour of shoots as against roots was evidenced under the molybdenum treatments. Whereas the light-loving parts of the plant behaved alike in this respect under the Molybdenum treatments, the roots showed great variations (Plate 1).

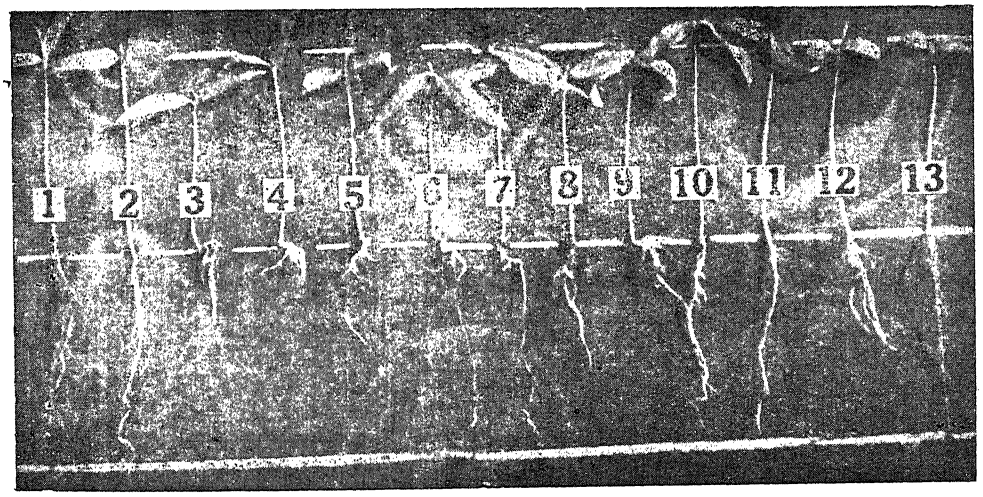

Plate 1. Effect of varying levels of micronutrient supply on the growth of *Cajanus cajan* at 34-day age. 1 : Ba ; 2 : Bb ; 3 : -B ; 4 : Zna ; 5 : Znb ; 6 : -Zn ; 7 : Mna ; 8 : Mnb ; 9 : -Mn ; 10 : Moa ; 11 : Mob ; 12 : -Mo ; 13 : control (Mon).

Roots—Moly-deficient and control series showed similar trend of effect in root ramification declining between 20–27 days after which the number increased consistently with age. The number of roots kept on inrceasing in the Moa or Mob treated plants, Mob proved to be more favourable towards ramification producing 28 rootlets, at the age of 41 days as against the initial of 21·3 rootlets (20-day age, table 1).

TABLE 1

The effect of levels of Molybdenum supply on the extent of branching (Average, no./plant)

Age (in days)	Levels of supply			
	-Mo	Mon	Moa	Mob
20	16·3	18·3	13·6	21·3
27	16·0	17·0	17·0	22·0
34	19·5	22·25	19·75	25·8
41	26·0	24·5	27·5	28·0

Moa series though having much lesser number of roots to begin with (13·6) progressed rapidly so as to double at 41-day age showing that this treatment was comparatively more conducive to rate of ramification (Table 1).

Plants did not show significant difference in their response to root number as between the deficient and control series though the former showed slightly higher rate of ramification of roots towards the end. Irrespective of the level of supply the number of roots increased in the period 27–41 days, the rate of rise being maximum for the Moa treatment in the last week of observation.

Linear Growth

Shoot—In shoot elongation the normally fed plants attained the maximum at the start, the values remained higher than the minus – molybdenum series at all the stages (Table 2). The Moa level of supply proved only slightly superior to the plants of the normally fed as well as the higher molybdenum supplied ones on the last day of observation.

The plants fed with Moa dose showed maximum increase in length of the shoots in the period under observation closely followed by the Mon, Mob and -Mo in succession, at the 41-day age.

TABLE 2

The effect of levels of Mo supply on the linear growth of Shoot (Average, cm/plant)

Age (in days)	Levels of supply			
	-Mo	Mon	Moa	Mob
20	6·93	8·00	6·66	6·16
27	10·17	11·66	11·3	11·425
34	10·25	11·575	12·87	11·76
41	9·5	13·025	14·9	12·2

Moly-fed plants exhibited a progressive increase in shoot length. At the 41-day age the Moa treatment proved the optimum in this regard.

TABLE 3

The effect of levels of Mo supply on the linear growth of Root
(Average, cm/plant)

Age (in days)	Levels of supply			
	-Mo	Mon	Moa	Mob
20	10·2	9·3	4·06	6·1
27	11·47	14·86	9·83	12·93
34	7·8	12·7	14·25	11·48
41	10·6	12·42	15·0	12·6

Root—The overall effect of molybdenum supply to *Cajanus* plants could be termed as excellent for Moa series followed by that under Mob, Mon and -Mo in succession. During the observed period, the root-length increased by about 11 cm., 6 cm., 3 cm. and 0·4 cm. respectively in these grades of molybdenum supply (Table 3). At the start, deficiency of molybdenum proved optimum for linear growth of root, though towards the end, moly-fed plants exhibited larger root-length.

The trend of the results indicated that larger supply of molybdenum proved more beneficial with advancing age. Better response by the molybdenum treated plants than the molybdenum deficient ones was recorded. The normal supply proved only next to the Moa level in this respect. The highest dose seemed not to be conducive to the linear growth of roots.

Dry matter Accumulation

Shoot—Moly supplied at the rate of 0·01 ppm as well as 2·5 ppm increased dry weight of shoots at 20-day age ; of the two the former augmented more than the latter. Under both the concentrations shoot dry weight decreased in the next week (Table 4). A steep fall in dry matter accumulation was noticed in the control plants while a gradual and to a lesser extent, in the Mob series in the second week under observation. In the subsequent fortnight plants of the Mob series showed some rise though in case of control plants it was not so.

TABLE 4

The effect of levels of Mo supply on the dry matter accumulation in Shoots
(Mean, gm/gm)

Age (in days)	Levels of supply			
	-Mo	Mon	Moa	Mob
20	·045	·049	·0398	·045
27	·027	·03	·03	·044
34	·030	·04	·032	·044
41	·035	·04	·038	·054

The moly-deficient as well as the Moa fed plants showed identical trend of steep fall followed by gradual though insignificant increase. In general, shoots suffered a set back in the accumulation of dry matter between 20-27 day age of plants. When molybdenum supply was disturbed this was accompanied by a rise in the dry weight of the roots (*cf.* Table 5).

Plants receiving normal supply of molybdenum showed similarity in behaviour with respect to augmentation of dry matter of the roots and shoots during the 27–41 days period. Larger supplies of molybdenum proved conducive to better dry matter production.

TABLE 5

The effect of levels of Mo supply on the dry-matter accumulation in Roots (Mean, gm/gm)

Age (in days)	Levels of supply			
	-Mo	Mon	Moa	Mob
20	·0053	·0055	·0046	·0046
27	·006	·0066	·0078	·0055
34	·006	·0075	·007	·0075
41	·0068	·0076	·0072	·0072

Root—At the 20-day age plants fed on normal quantity of molybdenum proved superior to others in augmenting maximum of dry matter ; those fed on Moly-deficient solution stood second in this regard (Table 5).

0·01 ppm level of supply of molybdenum proved optimum for the dry matter production of roots at the initial stage. Increase in the level of Mo supply to Moa and Mob level depressed dry-matter production in the pre 20-day period. However, the dry-matter accumulation in the following period was such that Moa could augment the maximum quantity of dry-matter, on the 27th day. Each of the two additional levels of supply depicted almost the same dry weight. At the start, this kept on increasing in the Mob series upto the 27th day and in the Mob to the 34th day suggesting that Molybdenum was utilized in the root dry-matter production to a greater extent with increase in age of the plants.

The increase in the former (Moa fed plants) was more than the latter (Mob) during 20-27 day period but as the former suffered a set back in the next week, both the treatments stood at the same level with respect to dry-matter accumulation at later stages. The behaviour in the last week under observation in the two treatments remained alike, both increasing dry-matter production of the roots to a small and equal extent.

Sugar Status

Shoots—Molybdenum supply to the tune of 2·5 ppm could accumulate maximum quantity of reducing sugars in the shoots of *Cajanus* throughout the period of experimentation except at the 34-day age, when normal supply surpassed it. Moa and control could accumulate equal amounts of reducing sugar at the 27 and also 41-day age. The former showing a reduction at 34-day age, while the latter exhibited great increase followed by a decline.

The deficiency series, behaved only next to Mob in the accumulation of reducing sugars at the 34 and 41-day age of the plants (Fig. 1).

Non-reducing sugars on the other hand were not affected so much by molybdenum concentrations ; almost equal values of non-reducing sugars accumulated by the control, Moa and Mob series at the 41-day age.

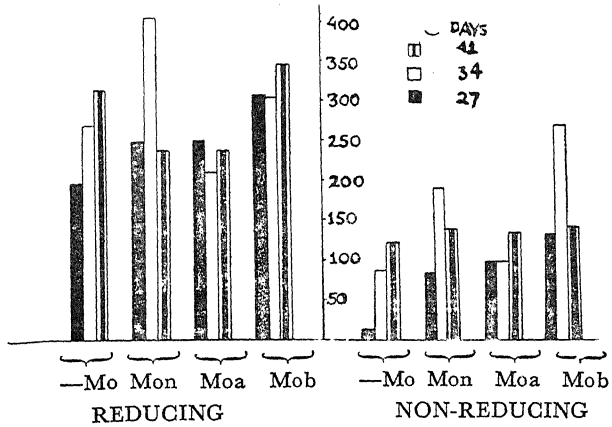

Fig. 1. The effect of various levels of molybdenum supply on the accumulation of sugar in shoots of *Cajanus cajan*.

Molybdenum supply of 1·25 ppm. proved slightly less effective than the control or Mob yielding 35·5 mgms/gm of the sugars while control and Mob possessed 140·40 mgms/gm. Molybdenum deficiency proved least conducive in the accumulation of non-reducing sugars when the content was only 124·0 mgms/gm (Fig. 1).

Roots—Contrary to the behaviour and response of shoots 2·5 ppm of molybdenum supply did not increase the accumulation of reducing sugars over control in roots though in the accumulation of non-reducing sugars the behaviour in the light-loving and light-avoiding parts of the plant was quite identical *vis-a-vis* the control.

The reducing sugar content of the plants raised under normal supplies of molybdenum surpassed those of the Mob series at the end though the plants of the latter series maintained the superiority in this respect upto the 34-day age (Fig. 2). Molybdenum supplied at 1·25 ppm proved least effective at the 41-day age though occupying second position at the 34-day age showing marked reduction in the accumulation of reducing sugars between 34 and 41-day age. During the same period molybdenum deficiency increased the rate of accumulation of reducing sugars with much rapidity.

In accumulation of non-reducing sugars, however, Mob proved highly effective, Moa and the deficiency taking the next position, while least effective was the control as revealed at the 41-day age.

There was no decline in the non-reducing sugar content at any stage in any of the treatments except the control and that too to a slight extent only at the 34-day age. The pattern of response of a level of Mo supply with respect to both reducing and non-reducing sugar was observed to be identical at the 27 and 34-day age of the plants. The percentage of sugars decreased with the level of supply.

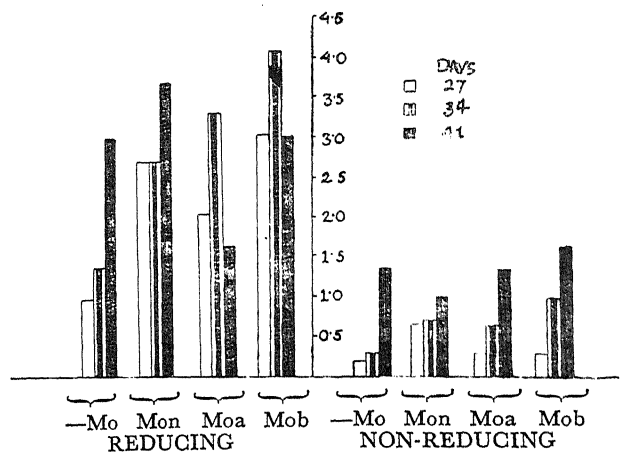

Fig. 2. The effect of various levels of molybdenum supply on the accumulation of Sugars in roots of *Cajanus cajan*.

Variations in Amino Acids

Change in level of molybdenum feeding varied the free amino acid content of plants (Table 6). Moly dificiency brought about general decrease of such amino acids, a few being severely affected. Depression of glutamic acid, with age, was noticed in all the levels of molybdenum treatment except the control. At the 27-day age, however, the glutamic acid content was a little higher in Mob treated than in the Moa or –Mo ones (Table 6).

Accumulation of arginine, glycine-serine and asparagine was stimulated by the application of Mob at 41-day age. Valine and γ-amino butyric acid were some of the other important amino acids affected by Mo treatment. β-alanine was noticed to disappear at the 41-day age in the Mob treated plants, though it was present in other series with less Mo supply or even in the deficiency of the Mo. Histidine and lysine could only accumulate in the highest concentration (Mob) at 34-day age to disappear later on.

In the Mob series the unidentified U, U_3, U_6, U_7 and U_{13} developed only at the 41-day age though not earlier. Of these only U was present in the Moly deficient plants at the 41-day age. Moly deficiency showed the presence of U_1 at the 27-day age and Moa formed U_1 and U_2 at the same age, all these vanished later. Moa formed U_5 at the 34-day age. Our results with the effect micronutrients on free amino acids in *Cajanus* have revealed that the number of free amino acids were less in the Mo deficient plants in contrast to their increase in the –B (Singh & Pal, 1963*a*) –Mn (Singh & Pal, 1963*b*) and –Zn ones. (unpublished data).

Discussion

Moly-feeding in doses, in excess of the control proved more conducive to root-ramification (*cf.* Table 1). Molybdenum behaved seemingly indifferently to branching of the shoot in the pre 41-day age of the plants. Plants of the deficiency series showed interveinal chlorosis, stunting, (*cf.* Table 2) and paleness of the tops. Similar symptoms have been reported by Johnson *et al* (1952) and Lobb (1953) under molybdenum deficiency conditions.

No symptoms of toxicity developed even in the plants of maximum supply suggesting that the *Cajanus* plants have a remarkable tolerance of molybdenum as

also reported by Hewitt and Jones (1949) or as stressed by Kozlowska (1951) that the supply of NO_3 to the plants checked the development of toxicity symptoms. It may be possible that the toxicity symptoms reported by Plant (1950) and Waring (1947) were not of universal occurrence since different plants have different degree of tolerance to the element as pointed out by Brenchley (1948) and Waring-ton (1937).

It seemed likely again that *Cajanus* seeds stored molybdenum in available form, much in excess of the requirements of the plant that emerged from the seed, more so in the pre 41-day seedling stage as also envisaged by Meagher *et al* (1952). The 1·25 ppm dose of molybdenum proved optimum for shoot growth while its deficiency deleterious for root elongation also. The Moa treatment proved optimum (*cf.* Tables 2 and 3). This aspect of the study of comparative influence on root and shoot elongation has not been reported so far.

In dry-matter accumulation of shoots Mob dose proved more efficacious in maintaining the same as against others where dry-matter accumulation showed a decline (*cf.* Table 4).

Incidentally, the maximum dose of molybdenum caused a steady increase in the dry-matter accumulation of roots (*cf.* Table 5). Higher level of Mo proved more useful for dry matter accumulation, as also reported by Anderson (1948) and Lal and Rao (1954) in contrast to the findings of Hewitt and Jones (1947) who observed abnormal growth in cabbage, cauliflower, tomato, mustard etc. when Mo was omitted from the nutrient solution.

In contrast to the present findings, significant response to Mo was noted in both dry-matter and protein yields in Alfalfa by Younge and Takashashi (1953). In these investigations leaf area of the plant increased as molybdenum supply was increased (Fig. 3), maximum being produced in Mob level of supply and minimum in the moly-deficient plants.

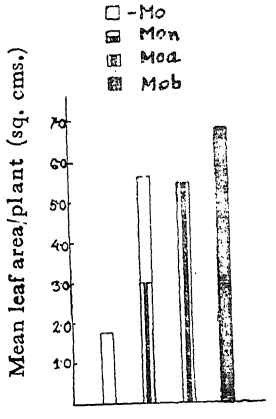

Fig. 3. Effect of molybdenum on leaf-expansion of *Cajanus cajan*.

Accumulation of reducing sugar in *Cajanus* shoots was enhanced by Mo upply of the tune of 2·5 ppm. In the accumulation of non-reducing sugars there was insignificant difference in the effectiveness of the Mob and Moa levels of supply, the latter proved slighty better. Agarwala and Williams (1952) reported that the concentration of various sugars was depressed at the lower levels of molybdenum.

TABLE 6

The Effect of Levels of Mo Supply on the free Amino acid Content in Shoots of *Cajanus*

Levels of supply	Age in days	Amino acids present																				
		1+2	3	4	5	6	7	8	10	12	15	16	18,19	20	21	22	U	U_1	U_2	U_5	U_6	U_7	U_{13}
-Mo	27	+	+	+	–	–	++	++	++	–	++	+	++	–	–	–	–	–	–	–	–	–	–
	34	–	+	–	–	–	+	–	–	–	+	+	+	+	++	–	–	–	–	–	–	–	–
	41	++	–	–	–	–	+	++	–	+	++	++	++	++	–	–	+	–	–	–	–	–	–
Mon	27	–	–	–	–	–	–	–	–	+	–	+	+	++	–	–	–	–	–	–	–	–	–
	34	++	–	–	–	–	++	++	+	–	+++	++	++	+++	–	–	–	–	–	–	–	–	–
	41	++	–	–	–	–	+++	++	++	–	+++	++	++	+++	–	–	–	–	–	–	–	–	–
Moa	27	+	+	+	–	–	++	++	++	+	+++	++	++	–	–	–	–	+	+	–	–	–	–
	34	–	+	+	–	+	+	+	–	++	++	++	++	–	+++	–	–	–	–	++	–	–	–
	41	–	+	+	–	+	+	+	–	++	+++	–	++	–	+	–	–	–	–	–	–	–	–
Mob	27	++	+	+	–	–	++	++	+++	–	++	+	+++	–	–	–	–	–	–	–	–	–	–
	34	–	–	–	–	–	+	++	–	+++	+	+++	++	–	+	++	–	–	–	–	–	–	–
	41	+	+++	+++	–	–	–	++	–	–	++++	++	++++	++++	–	–	+++	–	–	++	++	++	++

1+2—Leucines + phenylamines ; 3—valine ; 4—γ amino butyric acid ; 5—tyrosine ; 7—α alanine ; 8—β alanine ; 10—glutamic acid ; 12—threonine ; 15—arginine ; 16—aspartic acid ; 18, 19—glycine, serine ; 20—asparagine ; 21—glutamine.

Rf values of unidentified amino acids : U = 0·856 ; U_1 = 0·264 ; U_2 = 0·488 ; U_5 = 0·672 ; U_6 = 0·84 ; U_7 = 0·800 ; U_{13} = 0·06.

Reducing sugar content of root proved to be higher under normal or deficient supplies of molybdenum than its supra supply (Figs. 2 and 3). Moly deficiency resulted in decrease of amino acids. Depression of glutamic acid in cauliflower under moly deficient conditions is on record (Agarwala and Williams, 1952). Reduction and fixation of amino acids has been reported by Hewitt (1949).

Increased level of molybdenum increased the accumulation of arginine, glycine serine and asparagine (*cf.* Table 6). Most pronounced changes for arginine, alinine, aspartic acid, glutamic acid were reported in 1949 by Hewitt and associates.

Glycine and Lysine accumulated in the Mob treated plants only at the 34-day age but disappeared later on, similarly in the unidentified series of amino acids, the Mob treated plants possessed the largest number. That the stimulation of the production of amino acids in plants depended on the presence of Mo is shown.

Summary

The differential response of molybdenum on the light-loving and light-avoiding parts of *Cajanus cajan* has been investigated under controlled pot culture conditions kept in diffused day light. The levels of moly supply used as treatments were –Mo, Mon, Moa and Mob representing deficiency, 0·01 (considered as normal), 1·25 ppm and 2·5 ppm respectively. Measurements were made of branching, linear growth, dry-matter accumulation, sugar status and variation in amino acid content of the two differently light-guided components of the plant over a period of 41-days from germination.

Branching of shoots remained unchanged under the various moly levels though the roots behaved differently with the dose of supply. While Moa treatment proved optimum for the rate of elongation of both the shoot and the root, the –Mo was least conducive. Dry-matter accumulation of shoots remained stationery under the Mob level of supply. Maximum increase was in the Moa and the Mob series for roots during the 20-41 day period of growth. For reducing sugars of both shoots and roots Mob treatment proved optimum though in the case of non-reducing sugars no resemblance in the effect could be established.

Mo deficiency resulted in decrease of free amino acids in shoot. With age, glutamic acid content was depressed irrespective of the level of Mo supply. Accumulation of arginine, glycine and serine, and asparagine was stimulated to the maximum by Mob at the 41-day age while β–alanine disappeared under similar conditions. Maximum level of molybdenum helped in the maximum accumulation of histidine and lysine at the 41-day age. Large number of unidentified amino acids also developed in the Mob treatment. The results have been discussed in the light of available literature.

References :

Agarwala, S. C. and Williams, A. H. *Ann. Rept. Agr. and Hort. Research Sta.* Long Ashton, Bristol, 66–70, 1952.

Anderson, A. J. *Journ. Austr. Inst. Agric. Sci.*, **14** : 28–32, 1948.

——— and Moye, D. V. *Aust. Journ. Agric. Res.*, **3** : 95, 1952.

——— and Spencer, D. *Aust. Journ. Sci. Res.*, **3** : 414, 1950.

Arnon, D. I. *Amer. Journ. Bot.*, **25** : 322–325, 1938.

Bear, F. E. Sea Salt and Molybdenum in the County Agent and VO-AG. Teacher, 1955.

Brenchley, W. E. and Warington, K. *Nature*, 149, 196, 1942.

Brenchley, W. E. *Ann. Appl. Biol.*, **35** : 139–160, 1948.

Buchan, J. L. and Savage, R. I. *Analyst*, **77** : 401–406, 1952.

Consdon, R., Gordon A. H. and Martin A. J. P. *Biochem. Journ.*, **38**: 224-232, 1949.

Cripps, G. S. *Amer. Vegetable Grower*, April issue, 1956.

Fowden, L. *Ann. Bot.*, **18** : 417–440, 1959.

Hewitt, E. J. and Jones, E. W. *J. Pomol. Hort. Sci.*, **23** : 254–262, 1947.

——— *Ann. Rept. Agric. Hort. Res. Sta. Long Ashton*, Bristol, 81, 1949.

Hewitt, E. J. *Intern. Congs. Biochem.* Abstracts of communications, Cambridge England, pp., 486–487, 1949.

——— Jones, E. W. and Williams, A. H. *Nature*, **163**, 681–682, 1949.

——— Bolle Jones, E. W. and Miles, P. *Plant and Soil*, **5** : 205, 1952.

Johnson, C. M., Pearson, G. A. and Stout, P. R. *Plant and Soil*, **4** : 178–196, 1952.

Kline, C. H. *Agl. Chemicals*, pp. 1–7, 1954.

Kozlowska, A. *Bull. Intern. Acad. Palon Sci., inath. Nat. Ser.* **B. 1** : 205–33, 1951.

Lal, K. N. and Subba Rao, M. S. Micro Element Nutrition of Plants. B. H. U. Press, 1954.

Lobb, W. R. *Newzealand Journal Agr.*, **87** : 3–11, 1953.

Meagher, W. R., Johnson, C. M. and Stout, P. R. *Plant Physiol.*, **27** : 223–30, 1952.

Mulder, E. G., Boxma, R. and Van Veen, W. L. *Plant and Soil*, **10** : 335–55, 1959.

Plant, W. *Nature*, **165** : 533, 1950.

Purves, E. R. *Agl. and Food Chem.*, **3** (8) : 666–669, 1955.

Ranjan, S., Govindjee and Laloraya, M. M. *Proc. Nat, Inst. Sci. India*, **21** : 42–47, 1955.

Russell, E. J. Soil conditions and Plant growth. Longmans Green & Co., 1950.

Rubins, E. J. Rural New Yorker, June 4, Issue, 1955.

Sheffild, F. M. L. *Ann. Appl. Biol.*, **35** : 131–136, 1943.

Singh, A. and Archana Pal. *Proc. Nat. Acad. Sci.* Sec. B., Vol. XXXIII, Part II, 216–226, 1963*a*.

——— *Ibid.*, Part IV, 571–582, 1963*b*.

Steward, F. C., Wetmore, R. H., Thomson, J. F. and Nitsch, J. P. *Amer. Journ. Bot.* **41** : 123–134, 1954.

Somogyi, M. *Journal of Biol. Chemistry*, **160** : 161, 1945.

Subba Rao, M. S. 1951. Cited by Lal and Rao, 1954.

Waring, E. J. *et al. Journ. Austr. Dnstt. Agric. Sci.*, **13** : 187, 1947.

Warington, K. *Ann. Appl. Biol.*, **24** ; 475–493, 1937.

Younge, O. R. and Takashashi, M. *Agron. Journ.*, **45** : 420–28, 1953.

NITROGEN FIXATION BY THE ENDOPHYTIC ALGA FROM THE CORALLOID ROOTS OF *CYCAS REVOLUTA*

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Blue-green algae, particularly species of *Nostoc* and *Anabaena*, frequently occur in association with other plants and there is definite evidence that some of the algae concerned can fix atmospheric nitrogen (Winter, 1935 ; Lhotsky, 1946 ; Henriksson, 1951 ; Bortels, 1940 ; Harder, 1917 ; Bond and Scott, 1935 ; Douin, 1953*a*, 1955 ; Venkataraman, 1960, 1962). The alga used in the present investigation was isolated from the coralloid roots of *Cycas revoluta* and was grown in bacteria-free cultures, using methods already described (Venkataraman, 1961, 1962).

Experimental :

In all experiments, unless otherwise stated, cultures were made in 100 ml. portions of a nitrogen-free Allen's No. 3 medium (Allen, 1952) contained in 250 ml. 'Pyrex' conical flasks. The basal medium was supplemented with A_5 micronutrient solution (1 ml/l) (Kratz and Myers, 1955) and the pH adjusted to 7·5. A portion of the material from an actively growing culture was shaken with sterile medium. The heavier material was allowed to settle and portions of 1 ml. of the supernatant suspension were used as inocula. Cultures were aerated in an assembly similar to the one suggested by Fogg (1942). Cultures were tested for bacterial contamination (Venkataraman, 1961) and the contaminated cultures were discarded.

Nitrogen estimations were done by the conventional micro-kjeldahl method and the percentage protein was calculated by multiplying the percentage nitrogen by 6·25.

Chromatographic analysis of the medium :

Cultures grown in 100 ml. conical flasks containing 25 ml. of the medium, were harvested after 5 days growth and the agla was separated by centrifugation for ten minutes at 3000 r.p.m. and by subsequent filtration. The filtrate was concentrated by evaporation and about 0·1 ml. of the concentrate was used for the chromatogram. The uninoculated control medium was also subjectd to a similar procedure. The amino-acids were examined qualitatively by means of single dimensional ascending chromatography, using *n*-butanol-acetic acid-water mixture (4 : 1 : 1). The free amino-acids in the algal body were examined qualitatively both by means of circular paper chromatography, using *n*-butanol-acetic acid-water mixture (4 : 1 : 1) as the solvent and by two dimensional paper chromatography, using water saturated phenol in presence of ammonia vapour as the first developing solvent and *n*-butanol-acetic acid-water mixture (4 : 1 : 1) as the second solvent (Jacob and Venkataraman, 1962 ; Venkataraman and Saxena, 1963). The spots were developed by spraying with ninhydrin solution (0·1 percent). The sugars in the medium were chromatographically examined by spraying with phloro glucinol (Borenfreund and Dische, 1957).

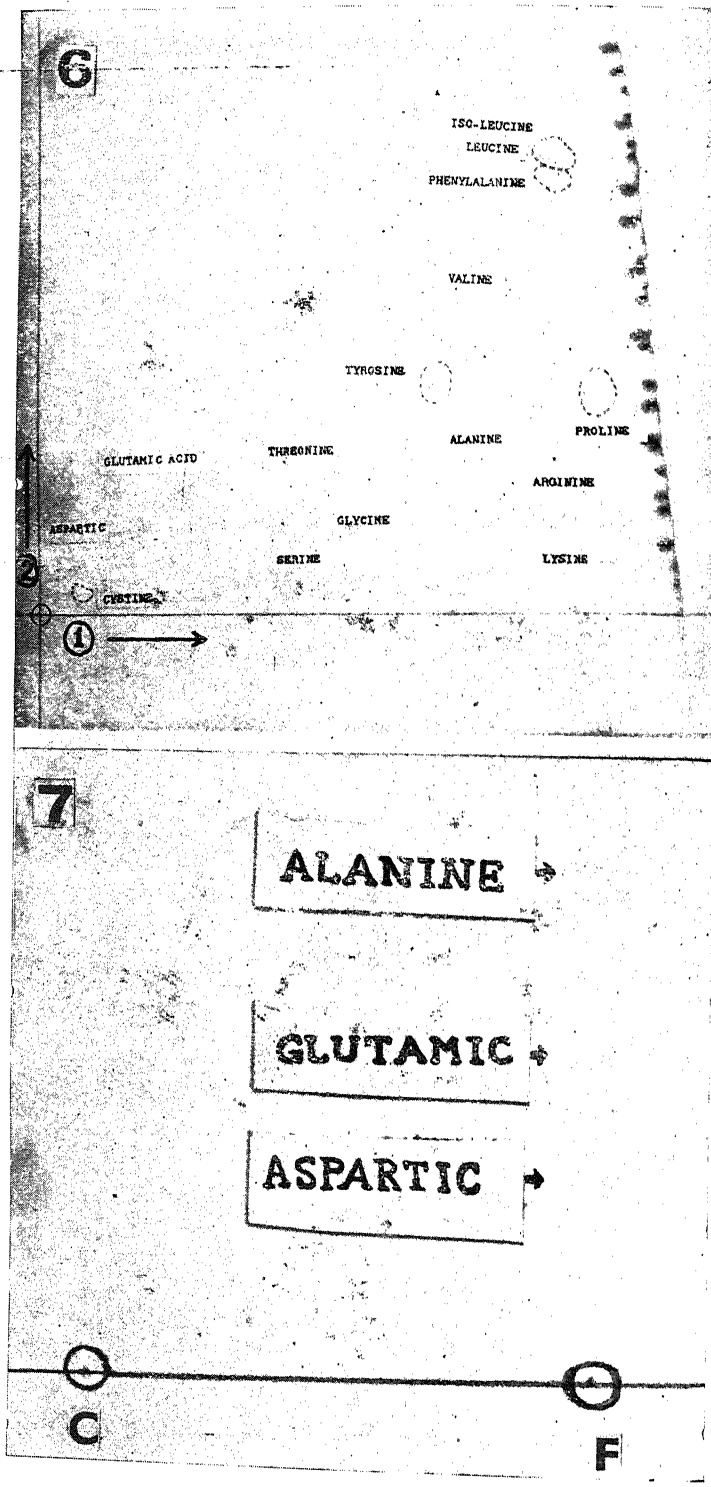

Fig. 6. Two dimensional chromatogram of the free amino-acids in the algal body (1, first dimension in water saturated phenol ; 2, second dimension in *n*-Butanol-acetic acid-water) ; Fig. 7. Single dimensional chromatogram of the amino-acids in the culture medium (C, uninoculated control medium ; F, medium in which the alga had grown).

them might have been derived by transamination (Watanabe, 1951). Besides these three free amino-acids, the alga was also found to liberate 21·13±0·1969 mμg vitamin B_{12} and related substances per 100 ml. of the medium, the synthesis of which is well known among blue-green algae (Brown *et al.* 1956 ; Henriksson, 1961 ; Okuda and Yamaguchi, 1960). Sugars were not detected in the medium.

The relation between the alga and the host is not very clear. While a simple 'space parasitism' leading to a heterotrophic existence of the alga within the host has been suggested (Harder, 1917 ; Geitler, 1932 ; Watanabe, 1924), a symbiotic relationship cannot be rulled out (Schaede, 1944), in view of the established nitrogen fixing capacity of the alga (Winter, 1935). Because of the occurrence of free amino-acids and vitamin B_{12} and related substances outside the cells of this alga, the immediate surroundings of the algal cells will form a special environment which may be favourable for the host.

Recently Watanabe and Kiyohara, (Micro-algae and photosynthetic bacteria, 1963, pp. 184–196) have isolated symbiotic blue-green algae from lichens, liverworts and cycads and found that these organisms could fix atmospheric nitrogen in free living state as well as in symbiosis with their host plants. They, however, treated the blue-green alga from the roots of *Cycas revoluta* as *Nostoc cycadeae*.

Summary :

Pure cultures of the endophytic alga from the coralloid roots of *Cycas revoluta* were tested for their ability to fix nitrogen and a fixation of 3·111±0·224 mg. N/100 ml. of the medium was obtained in fifteen days. The alga was also found to liberate vitamin B_{12} and related substances as well as three free amino-acids *viz.* aspartic acid, glutamic acid and alanine.

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References :

Allen, M. B. The cultivation of Myxophyceae. *Arch. Microbiol.*, **17** : 34–53, 1952.

Bond, G. and Scott, G. D. An examination of some symbiotic systems for fixation of nitrogen. *Ann. Botany*, **19** : 67–77, 1955.

Borenfreund, E. and Dische, Z. A new spray for spotting of sugars on paper chromatograms. *Arch. Biochem. Biophys.*, **67** : 239–40, 1957.

Bortels, H. Ueber die Bedeutung des Molybdäns für stickstöffbindende Nostocaceen. *Arch. Microbiol.*, **11** : 155–86, 1940.

Brown, F., Cuthbertsen, W. F. J. and Fogg, G. E. Vitamin B_{12} activity o *Chlorella vulgaris* Beij. and *Anabaena cylindrica* Lemm. *Nature*, **177** ; 188, 1956.

Chaudhuri, H. and Akhtar, A. R. The coral-like roots of *Cycas revoluta*, *Cycas circinalis* and *Zamia floridana* and the alga inhabiting them. *J. Indian Bot. Soc.*, **10** : 43–59, 1931.

Douin, R. Sur la fixation de l'azote libre par les Myxophycèes endophytes des Cycadèes. *Compt. rend.*, **236** : 956–58, 1953*a*.

——— Sur la polymorphisme de l'*Anabaena cycadeae* Reinke. *Rev. gen. Bot.*, **63** : 477–82, 1953*b*.

——— Nitrogen and carbon nutrition of *Anabaena*, endophytic in Cycadaceae. *Chem. Abstrs.*, **49** : 4811, 1955.

Fogg, G. E. Studies on nitrogen fixtion by blue-green algae I. Nitrogen fixation by *Anabaena cylindrica* Lemm. *J. expt. Biol.*, **19** : 78–87, 1942.

Geitler, L. *Cyanophyceae* in Rabenhorst's *Kryptogamen Flora*, **14** : Leipzig, 1932.

Henriksson, E. Nitrogen fixation by a bacteria free symbiotic *Nostoc* strain, isolated from *Collema*. *Physiol. Plantarum*, **4** : 452–55, 1951.

——— Studies in the physiology of the Lichen *Collema* IV. The occurrence of polysaccharides and some vitamins outside the cells of the Phycobiont, *Nostoc* sp. *Ibid*, **14** : 813–17, 1961.

Harder, R.. Ernahrungsphysiologische Untersuchungen an Cyanophyceen, hauptlich dem endophytischen *Nostoc punctiforme*. *Zeitschr. Bot.*, **9** : 145–242, 1917.

Hariot, P. Sur une algue qui vit dans les racines des Cycadees. *C. R. Acad. Sci.* Paris, **115** : 325, 1892.

Jacob, K. M. and Venkataraman, G. S. Amino-acid composition of *Chara corallina* Willd. *Phykos.*, **1** (2) : 95–97, 1962 (In press).

Kartz, W. and Myers, J. Nutrition and growth of several blue-green algae. *Amer. J. Botany*, **42** : 282–87, 1955.

Lhotsky, S. The assimilation of free nitrogen in symbiotic Cyanophyceae. *Studia bot. Cecheslov.*, **7** : 20–36, 1946.

Life, A. C. The tuber-like roots of *Cycas revoluta*. *Bot. Gaz.*, **31** : 265–71, 1901.

Methods of vitamin assay. Ed. Assoc. Vitamin Chemists Inc. 2nd Ed. 1951 Pub. Interscience Pub. Inc. New York.

Okuda, A. and Yamaguchi, M. Nitrogen fixing micro-organisms in paddy soils VI. Vitamin B_{12} activity in nitrogen fixing blue-green algae. *Soil and Plant Food*, **6** : 76–85, 1960.

Reinke, J. Zwei parasitische Algen. *Bot. Zeit*, **37** : 437–8, 1879.

Schaede, E. Ueber die Korallenwurzeln der Cycadeen und ihre Symbiose. *Planta*, **34** : 98–124, 1944.

Spratt, E. R. Some observations on the life-history of *Anabaena cycadeae*. *Ann. Bot.*, **25** : 369–80, 1911.

Takesige, T. Die Bedeutung der Symbiose zwischen einigen endophytischen Blaualgen und ihren Wirtspflanzen. *Bot. Mag.* Tokyo, **51** : 514–24, 1937.

Venkataraman, G. S. Nitrogen fixation and production of extracellular nitrogenous substances by an endophytic *Nostoc* strain, isolated from the root nodules of Egyptian Clover (*Trifolium alexandrinum*). *Proc. Symp. Algology*, New Delhi, December, 1959, 119–127, 1960.

——— Nitrogen fixation by *Stigonema dendroideum* Frèmy. *Indian J. agri. Sci.* **31** : 213–15, 1961.

——— Studies on nitrogen fixation by blue-green algae III. Nitrogen fixation by *Anabaena azollae*. *Ibid.*, **32** : 22–24, 1962.

——— Dutta, N. and Natarajan, K. V. *Idem*, I. Nitrogen fixation by *Cylindrospermum sphaerica* Prasad. *J. Indian bot. Soc.*, **38** : 114–119, 1959.

——— and Saxena, H. K. *Idem* IV. Liberation of free amino-acids in the medium. *Indian J. agri. Sci.*, **33** (1) : 1963 (In press).

Watanabe, K. Studies uber die Koralloide von *Cycas revoluta*. *Bot. Mag.* Tokyo, **38** : 167–87, 1924.

Watanabe, A. Production in cultural solution of some amino-acids by the atmospheric nitrogen fixing blue-green algae. *Arch. Biochem. Biophys.*, **34** : 50–55,1951.

Winter, G. Ueber die Assimilation des Luftstickstoffs durch endophytische Blaualgen. *Beitr. Biol. Pfl.*, **23** : 295–335, 1935.

STUDIES ON THE MORPHOLOGY AND HISTOLOGY OF THE DIGESTIVE TRACT AND ASSOCIATED STRUCTURES OF *CHAGUNIUS CHAGUNIO* (HAMILTON)

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Introduction :

Chagunius chagunio (Hamilton), a mud-fish belonging to the family Cyprinidae, is quite abundantly found in the rivers and rivulets of Dehra Dun. It is popularly called "Pathrali" or "Chhiban". It has a wide range of distribution, occurring throughout Northern India, Burma, Siam and Thialand.

Although exhaustive research work has been carried out on the morphology, histology and associated srtuctures of the alimentary canal of cyprinoid fishes, outside India (Hill, 1926 ; Rogick, 1931 ; Chu, 1935 ; Curry, 1939 ; Al-Hussaini, 1949 ; and Girgis, 1952), it has remained rather neglected in India. Except the work of Sarbhai (1939) on *Labeo rohita*, the remaining accounts are fragmentary and inadequate (Das and Moitra, 1956 ; Mazumdar and Saxena, 1961 ; and Khanna, 1961). Especially, the work of Khanna (1961), who has tried to study the morphology of half a dozen cyprinoid fishes, is so meagre that it can hardly be relied upon. However, from a careful survey of the available literature, it appears that other teleostean families have received considerable attention, especially the families Salmonidae (Gulland, 1898 ; Greene, 1912 and 1914), Clupidae (Bapat and Bal, 1950 ; Kapoor, 1954 ; Srivastava, 1958 ; and Swarup, 1959), Mugilidae (Ishida, 1935 ; Ghazzawi, 1933 and 1935 ; and Pillay, 1953) and Siluridae (Ahsan-ul-Islam, 1951 ; and Kapoor, 1953). Al-Hussaini's new approach to study the anatomy and histology of the alimentary canal in relation to the feeding habits is interesting (Al-Hussaini, 1945, 1946, 1947 and 1949) His valuable contributions have been further enriched in collaboration with Kholy (Al-Hussaini and Kholy, 1953). Chu's (1935) description on the pharyngeal teeth of different cyprinoid fishes is also very helpful.

Therefore, after making a careful survey of the literature on the alimentary canal of fishes, it was considered desirable to study the morphology and histology of another commonly available cyprinoid fish, *Chagunius chagunio* and the results obtained are considered worth publishing.

Material and Methods :

The fish, *Chagunius chagunio*, were collected from the river Assan, a tributory of Jamuna near Herbartpur and from river Susva near Kansro. The length of the specimens obtained ranged from 20 to 22·5 cm.

The specimens were immediately dissected out carefully to study the gross anatomy of the alimentary canal. By giving a median longitudinal incision to the entire alimentary canal, the disposition of the mucous folds was also studied.

For histological details, alive fish were dissected out and small pieces of the various regions of the alimentary canal and associated structures were immediately fixed in Bouin's fluid. Fixation was carried out for 20 to 24 hours. After usual dehydration and embedding, transverse sections of the material were cut at 6 to 10 micra. Sections were stained by Delafield's and Heidenhain's iron-haematoxylin, counter-stained with eosin. The diagrams were drawn with the help of a camera lucida and the minute details were added free hand.

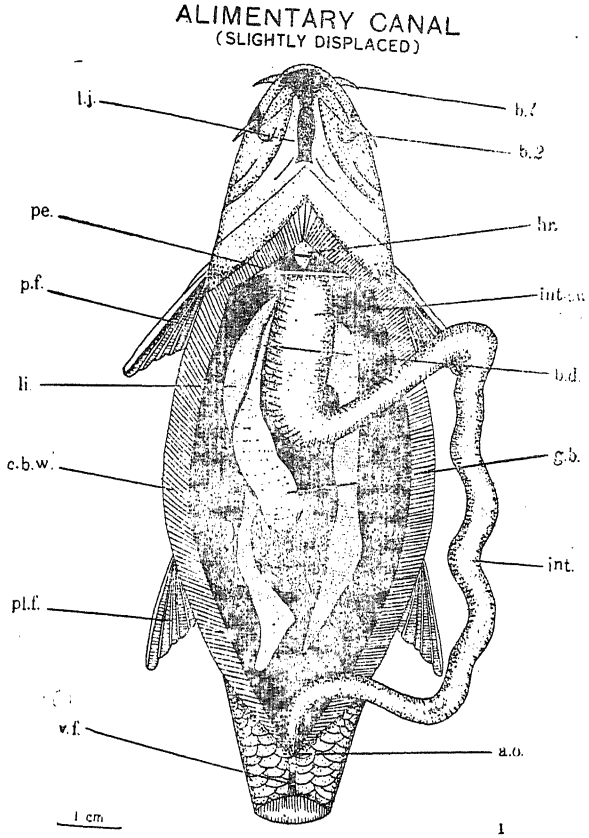

Fig. 1

Observations :

Morphology : The alimentary canal of *Chagunius chagunio* is a coiled tubular structure (Fig. 1) which extends throughout the coelomic cavity. It can be distinguished into a buccal cavity, pharynx, oesophagus, intestinal-swelling, intestine and rectum. The rectum, however, cannot be distinguished externally.

Buccal cavity (Fig. 2).—The mouth, which is situated at the tip of the snout, is a crescent-shaped opening. The gape of mouth is not wide and does not extend beyond the eyes. It leads into the buccal cavity which is dorso-ventrally flattened. The mucous membrane of the floor of the buccal cavity is elevated and thickened to form a rudimentary tongue. On the roof of the buccal cavity the mucous membrane is finely ridged and, at its anterior end and just behind the upper lip, there is a thick membrane—the velar membrane which is crescentic in shape.

Pharynx—The buccal cavity narrows down posteriorly into the pharynx which is also dorso-ventrally flattened. Its roof is supported by the base of the cranium and the floor by the median basibranchical and hypobranchial elements of the branchial arches. The sides are bounded by the cerato- and epihyal elements. The pharynx can be distinguished into two portions—an anterior and a posterior pharynx.

The anterior pharynx constitutes the pharyngeal apparatus which is narrow in front but widens posteriorly, reaching its maximum near the beginning of the posterior pharynx. It is perforated latero-ventrally by the gill-slits through which the pharyngeal cavity communicates with the branchial chamber. The wall of the anterior pharynx is lined by thick mucous membrane. The gill-rakers of the first row are the longest (Fig. 2). Each gill-raker has two rows of processes on it which appear as muscular outgrowths.

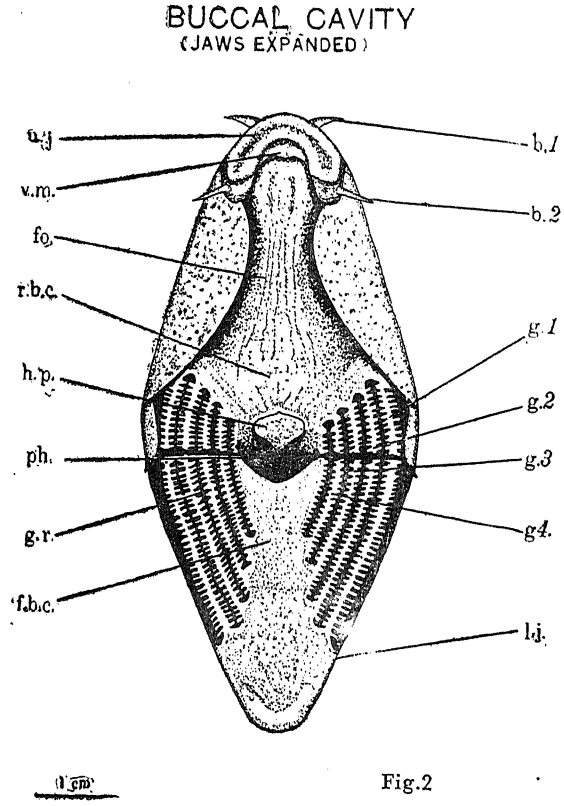

Fig.2

The posterior pharynx consists of a small chamber, broad in front and narrow behind. Its roof bears a horny pad while the floor is provided with two sets of pharyngeal teeth borne on a pair of inferior pharyngeal bones of the fifth arch. The teeth are arranged in three rows in the order of 2, 3, 5/5, 3, 2. These are closely beset and work against the horny pad. The teeth are conical. These are all homodont and the dentition is of the polyphyodont type. The teeth together with the horny pad constitute a fine masticatory apparatus.

Oesophagus—The pharynx at its posterior end descends a little and passes into a narrow oesophagus. It is short and tubular and lies dorsal to the pericardium. After passing through the septum transversum, it emerges into the visceral cavity.

The mucous membrane lining the oesophagus, is thrown into a few longitudinal folds. Posteriorly, the oesophagus is continued into the intestinal-swelling or bulb.

Intestinal-swelling—It lies dorsal to the coils of the intestine and ventral to the air-bladder. The extensive mass of liver lobes lies on either side of it. The intestinal-swelling is a thick straight tube-like structure which lies in the anterior one-third of the visceral cavity. The mucous membrane of the intestinal-swelling is thrown into few low folds which by their union present a honey-comb pattern. The bile duct opens on an elevated papilla in the anterior part of the intestinal-swelling just close to the opening of the pancreatic duct. The intestinal-swelling narrows posteriorly and continues as the intestine proper.

Intestine—The intestine commences just after the intestinal-swelling. It is comparatively a thin-walled tube, which constitutes the major part of the alimentary canal. Its diameter is more or less uniform. It fills the entire posterior portion of the abdominal cavity. The mucous folds are fewer and are arranged in the form of low obliquely transverse folds. Duodenum cannot be made out externally since there is no clear demarcation.

Rectum—Towards the posterior end, the intestine norrows down and continues as the rectum. It is a short thick tube-like structure, measuring 12 mm. in a specimen of 22·5 cm. in length. Its internal wall contains thick longitudinal mucous folds. It opens to the outside through an anal aperture.

Glands associated with the alimentary canal :

The glands associated with the alimentary canal are liver and pancreas.

Liver—Liver of *Chagunius chagunio* is a compact elongated mass, dark-brown in colour, with two lobes—a narrow elongated right lobe and broad left lobe Fig. 1), each extending along the sides of the coils of the intestine and occupying a considerable portion of the abdominal cavity, reaching close to the posterior part of the intestine. The two lobes are not descrete all along their length but meet by transverse connections with each other at three places : (1) an anterior connection—at their anterior ends just after the pericardium where they lie on the ventral side of the cardiac region of the intestinal-swelling and fuse to form a common anterior mass attached to the posterior face of the septum transversum ; (2) a middle connection—about the middle of their length, the two lobes of the liver fuse to form a middle connection on the dorsal side of the intestinal-swelling, just at the point where the latter passes into the intestine ; and (3) a posterior connection—at the posterior end, the two lobes join across the ventral surface of the intestine. At this place the liver forms a more or less crescentic posterior median mass. Each lobe has several irregular divisions.

The gall bladder lies between the right lobe of the liver and intestinal-swelling. It is thin-walled and club-shaped structure. A thin-walled bile duct arises from the antero-ventral end of the gall bladder and runs forward between the right lobe of the liver and the intestinal-swelling for a distance of about 5–6 mm., where it receives the right hepatic duct from the right lobe of the liver. The bile duct now runs transversely for a very short distance and receives the

median hepatic duct from the median hepatic mass and the left hepatic duct from the left lobe of the liver. After receiving the three ducts, the bile duct runs obliquely towards the anterior part of the intestinal-swelling and opens into it.

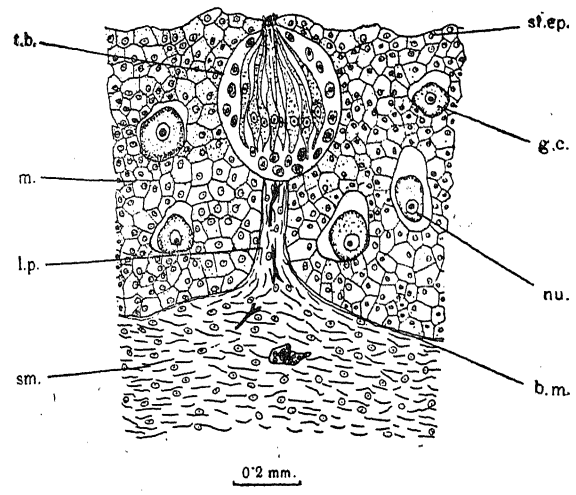

Fig. 3

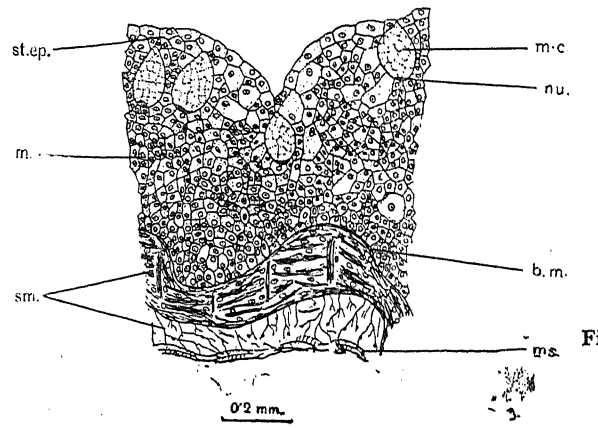

Fig. 4

Pancreas—Pancreas is a diffused, glandular mass which is spread over a greater part of the visceral cavity. It is also found as small bits surrounding the finer branches of the blood vessels. The hepatic ducts also bear the pancreatic tissue over them. The pancreatic tissue, especially in young specimens, cannot be easily traced but a careful microscopic examination at once reveals its identity. Several small ductules from different parts of the pancreas come near the right hepatic lobe and unite to form a pancreatic duct. It runs along the bile duct and opens into the anterior part of the intestinal-swelling.

Histology :

The histology of the lips is essentially the same as that of the skin. There is an outer layer, epidermis, followed by dermis (Fig. 3). The epidermis consists

of a stratified epithelium, taste buds and giant cells. The stratified epithelium rests on a basement membrane. The cells of the stratified epithelium are many-sided and each has an oval or rounded nucleus. The taste buds are flask-shaped and two kinds of cells are found in them—(*a*) the neuro-epithelial cells which are spindle-shaped, each having an oval nucleus, and (*b*) the supporting cells which are located towards the base and the sides. Each taste bud or gustatory organ is surrounded by stratified epithelium and is supported on lamina propria. It communicates to the outside through its neck by a gustatory pore. The large number of taste buds on the lips point to a highly developed gustatory sense in the fish.

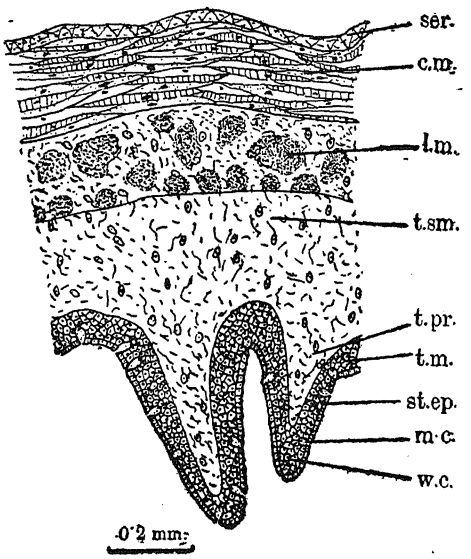

Fig. 5

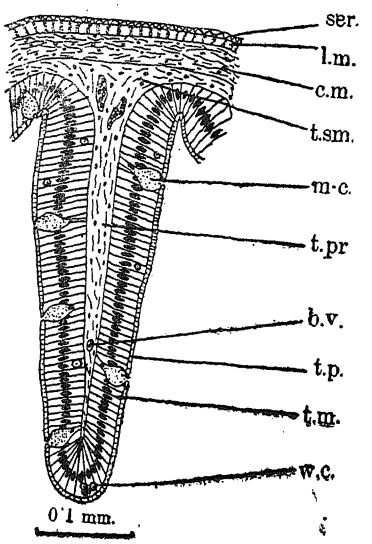

Fig. 6

Alongwith the taste buds, a large number of 'giant cells' are also observed. The giant cells are generally oval in outline and fairly bigger than the other cells of the epidermis. Each cell is located in an inter-cellular space which is not always completely occupied by it. The cytoplasm stains deep red with eosin.

Below the epidermis is observed a non-cellular layer, the basement membrane. Beneath the basement membrane is the dermis which chiefly consists of connective tissue, blood capillaries and nerve fibres. At places, generally below the taste buds, the dermis projects into the epidermis in the form of a finger-shaped papilla. The papilla consists of dense connective tissue and nerve endings.

The buccal cavity is made up of mucosa, sub-mucosa and muscularis (Fig. 4). The mucosa consists of striated epithelium in which are embedded numerous mucous cells. Each cell is polygonal or quadrangular in outline with an oval or spherical nucleus. The nucleus may be either at the centre or slightly displaced. The mucous cells are modified epithelial cells and are bigger and flask-shaped. These secrete mucous and are generally so full that the nucleus is pushed towards the base and appears to be spindle-shaped. The mucous cells may occur singly or in groups.

The mucosa is followed by the sub-mucosa which consists of two layers—an inner and an outer layer. The inner layer mostly consists of circularly disposed connective tissue fibres which at places are interrupted by radial or longitudinal connective tissue fibres. The outer layer consists of loose connective tissue fibres. Both the layers are highly vascular. Striated muscles are present below the sub-mucosa.

The oesophagus is made up of mucosa, sub-mucosa, muscularis and serosa (Fig. 5.) Mucosa is thrown into numerous folds and the cells are polygonal with centrally placed nuclei. They are provided with a basement membrane which is better seen at places where the epithelium is separated from the lamina propria. Lamina propria projects into the mucosa and is made up of collagenous connective tissue fibres. It is highly vascular. Mucous cells are in abundance in mucosa. Sub-mucosa consists of collagenous connective tissue fibres. The muscularis comprises of an outer circular layer and an inner longitudinal layer of muscles. The serosa consists of fibrous connective tissue and is peneterated at several places by blood capillaries. The layer is packed with sub-serous connective tissue bundles. Histological details are, however, different in the portion where oesophagus passes into the intestinal-swelling. The fundamental difference lies in the gradual transformation of striated epithelial layer of mucosa of the oesophagus into the columnar epithelium of the intestinal-swelling.

The wall of the intestinal-swelling is similarly formed of four coats which from inside out are the mucosa, sub-mucosa, muscularis and serosa (Fig. 6.) Mucosa is a single-layered thick membrane which is thrown into a number of folds Each epithelial cell is slender, columnar and is provided with a top plate. The nucleus is oval and located near the centre of the cell. The mucous cells are scattered in between the epithelial cells. The wandering cells are in abundance and possess small nuclei. The gastric glands are absent and the digestive function is performed by the bile and pancreatic juices which are poured in the anterior portion of the intestinal-swelling. The mucous cells are fewer. Sub-mucosa consists chiefly of loose connective tissue with a number of blood vessels and capillaries traversing through the same. Muscularis is formed of two layers of muscle fibres. The outer layer is thin and consists of longitudinally arranged fibres. The inner layer is quite thick and is formed of circularly arranged muscle fibres. Serosa is a thin-walled cellular membrane.

The histological details of intestine (Fig. 7), which constitutes the major part of the alimentary canal, are also similar to those of the intestinal-swelling but different from the rectum. Mucosa consists of typical columnar cells which are long and slender with large central nuclei. The cells are bordered by the top plates except at places where mucous cells are interspersed among the columnar cells. The mucous cells provide lubrication and also protection to the delicate intestinal mucosae against abrasion. Small wandering cells are scattered among the epithelial cells. Lamina propria is made up of connective tissue in which run the blood capillaries. Sub-mucosa, like that of the intestinal-swelling, is made up of connective tissue with an abundant vascular supply. Muscularis consists of a large inner coat of circularly arranged muscles and an outer coat of longitudinal msucle fibres. Serosa is single-layered and is also like that of the intestinal-swelling.

The wall of the rectum is relatively thicker than that of the intestine (Fig. 8). Mucosa is lined by the columnar epithelium in which are embedded mucous cells which are comparatively abundant. Epithelial cells are provided with top plates as in the intestine but their nuclei are conspicuously placed towards their

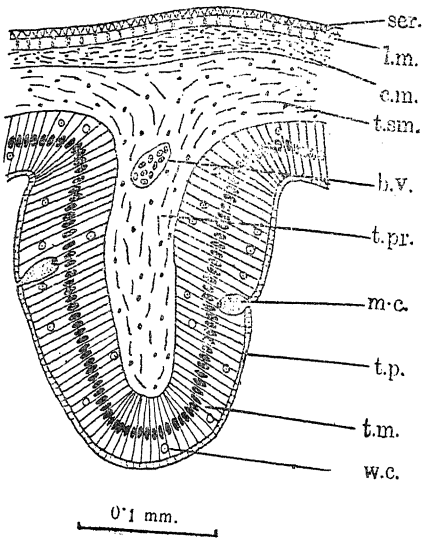

Fig. 7

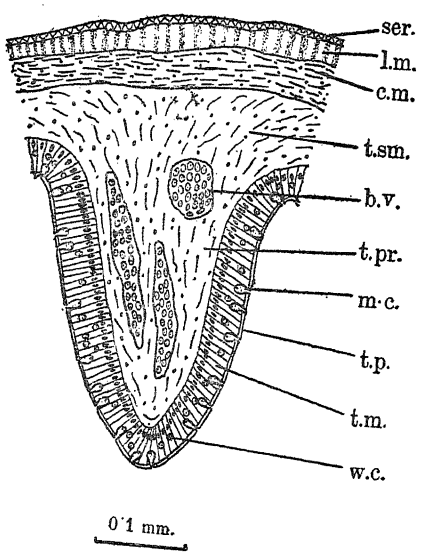

Fig. 8

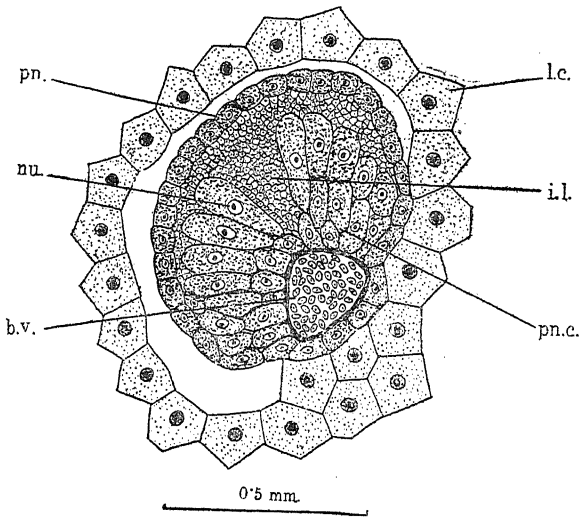

Fig. 9

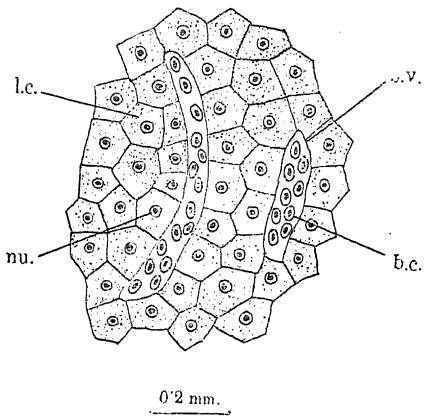

Fig. 10

ABBREVIATIONS USED

a.o.—Anal opening ; b_1 and b_2—Barbels ; b.c.—Blood corpuscles ; b.d.—Bile duct; b.m.—Basement membrane ; b.v.—Blood vessel ; ; c.b.w.—cut body wall ; c.m.—Circular muscles ; f.b.c.—Floor of the buccal cavity ; fo.—Fold ; g.b.—Gall bladder ; g.c.—Giant cell ; g .r.—Gill-rakar ; hr.—Heart ; h.p.—Horny pad ; int.—Intestine ; int. sw.—Intestinal-swelling ; i·l.—Islets of Langerhans ; li.—Liver ; l.c.—Liver cells ; l.j.—Lower jaw ; l.m.—Longitudinal muscles ; l.p.—Lamina propria ; m.—Mucosa ; nu.—Nucleus ; m.c.—Mucous cell ; pe.—Pericardium ; ph.—Pharynx ; pn.—Pancreas ; pl.f.—Pelvic fin ; r.b.c.—Roof of the buccal cavity ; r.—rectum ; sm.—Submucosa ; st. ep.—Striated epithelium ; t.b.—Taste bud ; t.m.—Tunica mucosa ; t.pr.—Tunica propria ; t.sm. Tunica submucosa ; u.j.—Upper jaw ; v. f.—Ventral fin ; v.m.—Velar membrane ; w.c.—Wandering cell.

bases. Sub-mucosa is, however, thicker. Muscularis is also comparatively thicker than that of the intestine. Serosa is of similar nature as observed in the intestinal-swelling. Towards the anal opening the mucous membrane changes gradually into a multi-cellular, thick and striated epithelium. A similar change in the elements of the muscularis coat is noticed *i.e.* from smooth to striated muscles.

A microscopic examination of the liver shows that it is made up of regular polygonal cells, the cytoplasm of which is highly granular, and the large rounded nuclei contain one or more nucleoli (Fig. 10). There is no definite arrangement of lobules in the liver lobes. A close network of hepatic capallaries, recognizable in sections by the presence of blood corpuscles, supplying the liver tissue is observed. Scattered in the liver tissue are very slender hepatic ductules, which join together to form hepatic ducts. Each ductule is lined with a single layer of cuboidal epithelium, the cells of which have large nuclei. Outside the epithelium, there is a connective tissue sheath, which acts as a support for the ductules.

The gall bladder is lined with columnar epithelium, which is surrounded on the outside by fibrous, muscular elastic tissue.

The pancreas exists in the form of a cellular investment around the blood vessels in the liver (Fig. 9) and also scattered in the visceral cavity. The pancreatic tissue is readily distinguished from that of the liver as it consists of large, cightly elongated cells, rich in "ferment granules" and forms lobules or acini. slach granular cell in an acinus has a characteristic structure, having a rounded Eucleus situated on one side of the cell. In addition to the pancreatic acini, a new irregular groups of cells are readily distinguished in the hepatic tissue since fhese take up a lighter stain than the other cells. These are the islets of Langerhans. In some cases these lie along one side of the pancreatic tissue loosely tattached to the acini, while in other cases the pancreatic tissue penetrates the tissue of these islets. This is owing to the diffused condition of the pancreas, which during development either invades or becomes attached to other organs of independent function. The islet-tissue is confined to the intra-hepatic portion of the pancreas since no such tissue has been observed in the diffused extra-hepatic pancreas. The cells of the islet-tissue are more or less polyhedral in shape and do not show the characteristic secretory granules of pancreatic cells.

Food and feeding habits :

Chagunius chagunio is generally known as the 'mud fish' in this area since it collects its food from the mud. Gut contents of a number of specimens were examined during the months of October, November and December. The intestinal-swelling was found to be quite distended and full. Temporary mounts of the gut contents when examined carefully led us to conclude that the fish feeds upon decayed organic matter, algae, arthropod larvae and rotifers. The intestine is approximately 1·8 times as long as the body. Judged by the length of the intestine and diversity of the food stuff, *Chagunius chagunio* is regarded as omnivorous.

The protrusible mouth becomes slightly inferior when the fish is feeding. It enables the fish to secure a good grasp of the food, especially the algal filaments and decayed organic matter. The barbels assist in finding the food burried in the mud. The gill-rakers constitute an efficient system to retain fine particles of food material within the pharynx. The food is well-masticated by the pharyngeal teeth which work against the pharyngeal pad. The position of the teeth behind the gills allows the fish to masticate its food in an elaborate manner without interfering with the process of respiration, which is also going on side by side. The

presence of a large number of taste buds shows a high gustatory sense which helps the fish in its selection of food.

Discussion :

In the cyprinoid fishes, the mouth is generally protrusible and is bounded by a pair of lips which in some cases are fleshy. In *Chagunius chagunio*, the protrusible mouth opening is directed obliquely downwards and is bounded by a pair of lips which are not fleshy. A number of giant cells are also discernible in the lips, the function of which is not clearly understood.

The buccal cavity, in the cyprinoid fishes, is provided with a palatal organ which is, generally, in the form of combplate (Girgis, 1952 ; and Mazumdar and Saxena, 1961). In other fishes, instead of the palatal organ, the mucous membrane of the roof of the buccal cavity is generally thrown into few to many longitudinal folds. The roof of the buccal cavity of *C. chagunio* is characterized by the absence of palatal organ but the mucous membrane is, however, produced into few longitudinal folds which are conspicuosly low. The floor of the buccal cavity, as is the case in general, is elevated to form a so-called rudimentary tongue. Taste buds are conspicous by their absence but instead, a number of mucous cells, are observed.

The gill-rakers, except those of the first arch, are quite characteristic as these bear tuft-like fleshy outgrowths. The processes of that of the first pair are, however, smooth. Generally, all the fishes which have been reported to be plankton-feeders, possess modified setiform gill-rakers invariably (Swarup, 1959). Such gill-rakers have also been described by Imms (1904) in *Polyodon* and Seitz (1937) in *Helostoma*. Suyehiro (1934) has compared the carnivorous, *Gadus macrocephalus* and plankton-feeder, *Theragra chalcogramma* and has shown that the former has coarse and short rakers which cannot collect fine food particles such as plankton while the latter has fine ones which can easily retain food particles. Al-Hussaini (1945, 1946, 1947 and 1949) has shown that different fishes with different feeding habits, namely, coral feeder, *Scarus sordidus*, the bottom-feeder, *Mulloides auriflamma* and plankton-feeder, *Atherina forskali*, possess variously modified gill-rakers, but in the first two fishes, the chief function of the gill-rakers is to protect the gill-filaments from the ill-effect of silt material, whereas in *Atherina*, these are primarily employed to strain food from the water. In *C. chagunio*, which is a 'mud fish', an efficient apparatus is required to ensure protection for the delicate gill-filaments against the ill-effects of sand and other particles which enter the anterior part of the pharynx. For this reason, probably, fleshy outgrowths appear on the gill-rakers.

The floor of the posterior pharynx of *C. chagunio* bears pharyngeal teeth. The shape of the pharyngeal teeth varies widely in different groups and Haekel (1841) described 13 varieties of pharyngeal teeth which were placed under four major divisions, *viz.*, (1) concave, (2) aggregated, (3) recurved with grinding surface, and (4) recurved without grinding surface. Recently, Chu (1935), who carried out a detailed and comprehensive study of the pharyngeal arches and teeth, distinguishes three principal categories of teeth in Cyprinidae, *viz.*, (1) compressed, (2) depressed, and (3) conical. The homodont teeth of *C. chagunio* are of the conical type according to the classification of Chu (1935).

As a rule, in the cyprinoid fishes, the pharynx is followed by oesophagus and then in succession by a stomach and intestine ; the latter terminates into a rectum. In some cyprinoid fishes, namely, *Barbus sarana*, *Barbus stigma*, *Chela bacaila*, *Amblypharyngodon mola*, *Esomus denricus*, and *Aspidoperia morar*, stomach is absent (Khanna,

1961). In these fishes, the oesophagus is followed by intestinal bulb. Intestinal bulb was first described by Rogick (1931) in *Campostoma anomalum*. Curry (1939) encountered a similar structure in the digestive tube of *Cyprinus carpio communis*, but termed it as the "large arm of the intestine". Recently, Girgis (1952), while describing the alimentary canal of *Labeo horie*, termed it simply as the "intestinal-swelling". At the same time certain authors (Das and Moitra, 1956) failed to distinguish the intestinal bulb from stomach (Khanna, 1961). Moreover, the histological details, especially the absence of gastric glands and the opening of the bile duct in the anterior part of the intestinal-swelling, amicably prove that it is a part of intestine. The same is confirmed by working out the histological details of the intestinal-swelling of *Chagunius chagunio*. It points out the same nature as described by Sarbhai (1939) for *Labeo rohita*. The intestine proper is large and a coiled structure.

Rectum has not been described in *Campostoma anomalum* (Rogick, 1931), *Cyprinus carpio communis* (Curry, 1939) and half a dozen cyprinid fishes named above (Khanna, 1961). On the other hand, a rectal region is described in certain fishes (Sarbhai, 1939; Al-Hussaini, 1945, 1946 and 1947). Al-Hussaini characterizes such abundance of mucous or goblet cells as distinguishing features of rectum. Purser (1928) and Girgis (1952) have also observed that goblet or mucous cells are in plenty in the last portion of the gut. In *C. chagunio* also the posterior part of the alimentary canal cannot be externally defferentiated as rectum but the histological details, especially the abundance of the mucous cells, justifies us to term it as rectum. The cloacal diverticulum is, however, absent in this fish.

The morphological and histological details of the liver of *C. chagunio* offer no interesting peculiarity in comparison to the liver of other cyprinoid fishes. The pancreas is, however, found as a complex diffused mass. Such a condition of pancreas was first observed by Macallum (1884) in *Amiurus*. Hill (1926) states that in teleostean fishes, the pancreas may be partially or wholly diffused, and remains more or less scattered all over the visceral cavity. Al-Hussaini is of similar opinion. In *C. chagunio*, pancreas occurs in two forms—intra-hepatic and extra-hepatic. Extra-hepatic pancreatic tissue is, however, scattered in the visceral cavity.

Summary:

Chagunius chagunio is an omnivorous fish and the alimentary canal can be differentiated into a buccal cavity, a wide pharynx, a short oesophagus, a bulbous intestinal-swelling, a considerably long intestine and a short rectum. Rectum, however, cannot be externally demarcated from the intestine. Stomach is absent. Liver and pancreas are the glands associated with the alimentary canal.

Mouth is a transverse slit-like aperture having prominent lips. Numerous taste buds or gustatory organs occur on the lips. Tongue is rudimentary and the buccal cavity is devoid of teeth.

Pharynx is well-developed and is provided with pharyngeal teeth which are homodont. A triangular horny pad is observed which lies embedded in the dorsal wall of the posterior pharynx. Gill-rakers, which are greatly modified, serve as an efficient sieve apparatus. The posterior pharynx passes into the intestinal-swelling through a short and narrow oesophagus.

Intestinal-swelling is bulb-like and is in direct communication with the intestine proper without having any external demarcation. The bile and pancreatic ducts open separately into the anterior part of the intestinal-swelling.

Intestine proper is a coiled tube. Rectum is characterised by the compactness of the villi and the abundance of mucous cells. It opens to the outside through a transverse slit-like opening, the anus, which is situated anterior to the urinogenital aperture.

Liver conforms to the general type observed in the teleostean fishes. Pancreas occurs in a diffused state. It is found embedded in the substance of the liver, generally around the blood capillaries. It also occurs scattered in patches throughout the visceral cavity.

References :

Ahsan-ul-Islam. The comparative histology of the alimentary canal of certain fresh-water Teleost fishes. *Proc. Ind. Acad. Sci.*, **33**-B : 297–321, 1951.

Al-Hussaini, A. H. The anatomy and histology of the alimentary tract of the coral-feeding fish, *Scarus sordidus* (Klunz). *Bul. Inst. d'Egypte*, **27**, 349–377, 1945.

——— The anatomy and histology of the alimentary tract of the bottom-feeder, *Mulloides auriflamma* (Forsk.)., *J. Morph.* **78** : 121–153, 1946.

——— The anatomy and histology of the alimentary tract of the plankton-feeder, *Atherina forskali* Rupp., *J. Morph.*, **80** : 251–286, 1947.

——— On the functional morphology of the alimentary tract of some fish in relation to differences in their feeding habits. Anatomy and histology. *Q. J. M. S.*, **90** : 109–139, 1949.

——— and Kholy, A. On the functional morphology of the alimentary tract of some omnivorous Teleost fish. *Proc. Egypt. Acad. Sci.*, **9** : 17–39, 1953.

Bapat, S. V. and Bal, D. V. The food of some young clupeids. *Proc. Ind. Acad. Sci.*, **32–B** : 39-58, 1950.

Chu, Y. T. Comparative studies on the scales and on the pharyngeals, and their teeth in Chinese Cyprinids, with particular reference of taxonomy and evolution. *Biol. Bull. St. John's Univ.*, No. **2** : 1–225, 1935.

Curry, E. The histology of the digestive tube of the carp, *Cyprinus carpio communis*. *J. Morph.*, **65** : 53–78, 1939.

Das, S. M. and Moitra, S. K. Comparative anatomy of the alimentary tract and its modifications in relation to feeding habits. *Proc. Nat. Acad. Sci.*, India, B, **28** : 224–233, 1956.

Ghazzawi, C. The pharynx and intestinal tract of Egyptian mullets, *M. cephalus and M. capito.* Part I, *Notes et Memoires de la Direction des Recherches des pecheries.*, Cairo, V. **5** : 1933.

——— *Ibid.*, Part II, *Ibid.*, V. **6** : 1935.

Girgis, S. On the anatomy and histology of the alimentary tract of a herbivorous bottom-feeding cyprinoid fish, *Labeo horie* (Cuvier). *J. Morph.*, **9** : 317–362, 1952.

Greene, C. W. Anatomy and histology of the alimentary tract of the King Salmon. *Bull. U. S. Bur. Fish.*, **32** : 73–100, 1912.

——— The fat-absorbing function of the alimentary tract of the King Salmon. *Bull. U. S. Bur. Fish.*, **33** : 1914.

Gulland, G. L. The minute structure of digestive tract of the Salmon and the changes which occur in it in fresh water. *Anat. Anz.* Jena, **14** : 1898.

Haekel, J. J. Ichthyologie. In Rossiger's Reisen in Europe, Asia and Africa, **I** : 1841.

Hill, W. C. O. A comparative study of the pancreas. *Proc. Zool. Soc.*, London, **1** : 616, 1926.

Imms, A. D. Notes on the gill-rakers of the spoon-bill sturgeon, *Polyodon spatuls*. *Proc. Zool. Soc.*, London, **2** : 1904.

Ishida J. The stomach of *Mugil cephalus* and its digestive enzymes. *Annot. Zool.*, Japan, **15** : 182–189, 1935.

Kapoor, B. G. The anatomy and histology of the pharyngeal organ in *Hilsa ilisha* (Ham.)., *Jour. Zool. Soc.*, India, **6** : 167–172, 1954.

Khanna, S. S. Alimentary canal in some Teleostean fishes. *Jour. Zool Soc.*, India, **13** : 206–219, 1961.

Macallum, A. B. Alimentary canal, liver, pancreas of *Amiurus catus*. *Proc. Canadian Inst.*, Toronto, New Series II, No. **3** : 387–417, 1884.

Majumdar, N. N. and Saxena, B. P. On the palatal organ of *Labeo dero* (Ham.). *Proc. Nat. Acad. Sci.*, India, Sec. B, **31** : 109–116, 1961.

Pillay, T. V. R. Studies on the food, feeding habits and alimentary canal of the grey mullet, *Mugil tade* Forskal. *Proc. Nat. Inst. Sci.*, India, **19** : 777–827, 1953.

Purser, G. L. *Calamoichthys calabaricus*. The alimentary and respiratory systems. *Trans. Roy. Soc.* Edin., **56** : 89–101, 1928.

Rogick, M. D. Studies of the comparative histology of the digestive tube of certain Teleost fishes. A minnow, *Campostoma anomalum. Jour. Morph.*, **52** : 1–25, 1931.

Sarabhai, D. S. The alimentary canal of *Labeo rohita*. *Jour. Asia. Soc.*, Bengal, **5** : 87–116, 1939.

Seitz, K. Untersuchungen Zur biologischen Anatomie der Ernahrung bei *Helostoma temmincki*. *Anat. Anz.*, Jena, **85** : 1937.

Srivastava, P. N. Primitive features in the alimentary canal of *Gadusia chapra* (Ham.). *Curr. Sci.*, Bangalore, **28** : 144–145, 1958.

Suyehiro, W. Studies on the digestive system and feeding habit of the important fishes of the North Pacific. I. The cods, *Gadus macrocephalus* (Tilesius) and *Theragra chalcogramma* (Pallas). *Bull. Jap. Soc. Fish.* Tokyo, **3** : 1934.

Swarup, K. The morphology and histology of the alimentary tract of *Hilsa ilisha* (Ham.). *Proc. Nat. Acad. Sci.*, India, Sec. B, **29** : 109–126, 1959.

STUDIES ON THE STRUCTURE AND BEHAVIOUR OF CHROMOSOMES OF *STREPTOPELIA TRANQUEBARICA* (HERMANN)

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[Received on 4th April, 1963]

Introduction :

The study of avian chromosomes attracted attention since the first decade of the current century. These investigations involve numerous difficulties which probably discouraged earlier workers and as a result very limited number of birds have been worked out as compared to the study of chromosomes in other groups of vertebrates and invertebrates. Moreover, the cytological studies of Indian birds have been totally neglected. A survey of literature reveales that whatever scanty information is available, deals with pet birds. In the present study the author has made an attempt to extend the knowledge further by studying the wild bird *Streptopelia tranquebarica* (Columbidae : Colunbiformes).

Material and Method :

The specimens were mostly collected at Allahabad from different localities within a radius of about 10 miles from the Zoological Laboratories. Usually the birds were brought alive to the laboratory and kept in cages. They were sacrificed immediately before fixation at regular intervals throughout the 24 hours of the day. The gonads were dissected out and fixed on the spot before the birds died. As the material under study proved to be difficult for the study of second meiotic cycle (because the process of divison is very quick and short-lived), the birds were injected intramuscularly with a weak aquous solution of colchicine about four hours before they were sacrificed, for the fixation of the gonads. The strength of the solution employed was 1·0 mg. for 100 cc. of distilled water and the qnantity injected varied from 0·5 to 2·0 ml. depending upon the size and the weight of the specimens.

The fixatives used were—Sanfelice, Bouin-Allen, Flemming's solution, Hermann's fluid and Champy's fluid. Champy's fluid, Bouin-Allen and Sanfelice proved valuable as they gave good results. Sections were cut at thickness ranging from 8–12 microns, and stained with Newton's Gentian violet, Heidenhain's haematoxyline, and Feulgen's stain.

The diagrams have been sketched with the aid of camera lucida, using 1/12 oil immersion objective, 25 × ocular at a level of about 25·6 cm. below the stage. The approximate magnification of figures being 8,000 X.

Observations :

The spermatogonial metaphase of *Streptopelia tranquebarica* has 60 chromosomes (Fig. 1). These exhibit a marked distinction into macro- and micro-chromosomes. The macro-chromosomes occupy a peripheral position encircling the micro-chromosomes, which lie centrally. A detailed analysis shows that the macro-chromosomes are in eight pairs. Of the four V-shaped macro-chromosomes, two

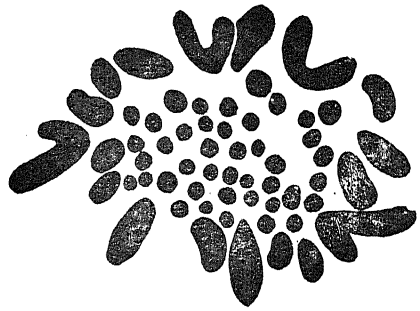

Fig. 1.

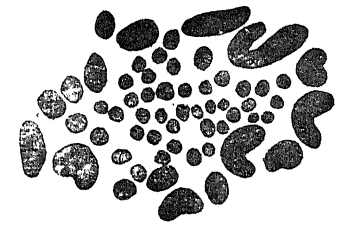

Fig.2.

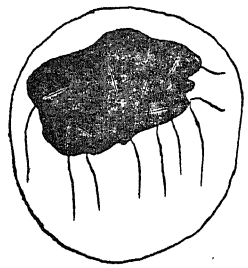

Fig.3.

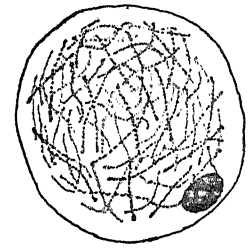

Fig.4

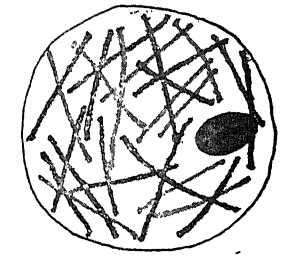

Fig. 5

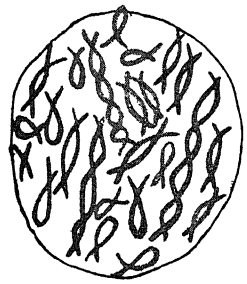

Fig. 6

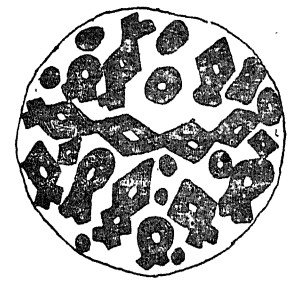

Fig. 7

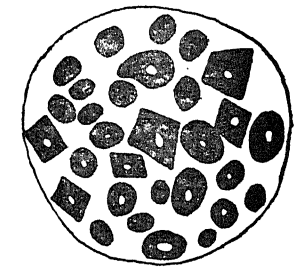

Fig. 8

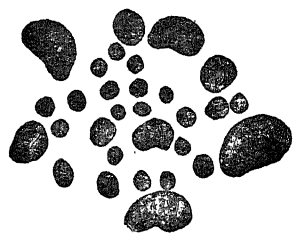

Fig. 10

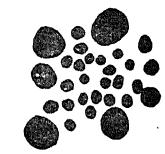

Fig. 11

Fig. 1. Spermatogonial metaphase plate of *Streptopelia tranquebarica* showing 60 diploid number of chromosomes (poler view) ; Fig. 2. Oogonial metaphase plate, showing 59 chromosomes (polar view) ; Fig. 3. Resting nucleus showing non-homologous association of chromosomes ; Fig. 4. Leptotene nucleus fine autosomal threads with heteropycnotic mass of sex-chromosome ; Fig 5. dachytene nucleus with heteropycnotic mass ; Fig. 6. Diplotene stage of meiosis ; Fig. 7. Diakinetic stage of meiosis ; Fig. 8. Prometaphase stage or late diakinetic stage of meiosis ; Fig. 9. First meiotic metaphase plate showing 30 bivalents (polar view) ; Fig. 10. First meiotic anaphase plate (polar view) ; Fig. 11. Second meiotic metaphase plate (polar view).

are mediocentric and two are sub-mediocentric, the latter possessing unequal arms. Of the remaining macro-chromosomes four are kidney-shaped, falling into two different size groups, and the rest are all acrocentric, rod-shaped chromosmes. The rod-shaped chromosomes may be further classified into three catagories *viz.*, two large, two medium and six small in size. The macro-chromsomes according to their shape and size can be formulated as—

$$aV + bJ + cR + dK + ek + fr + gr + hr = 16$$

V, R and K mark the V- rod- and kidney-shaped chromosomes of large size while *k* and *r* show similar kinds of chromosomes of smaller size. The micro-chromosomes are all spherical and rod-shaped and closely graded in size. They are 44 in number. At this stage the sex-chromosomes are indistinguishable from the autosomes, both being structurally alike.

The oogonial metaphase plate (Fig. 2) shows a diploid number of $2n=59$ chromosomes. Here too the chromosomes are distinctly of two types, the macro- and the micro-chromosomes. The macro-chromosomes are 15 in number, one less than in the male. The largest V-shaped chromosome with equal arms is seen without a homologue in the oogonial metaphase plate. Thus the largest macro-chromosome of the complement is the sex-chromosome and can be labelled as XO in the female and XX in the male. The remaining macro-chromosomes are morphologically similar to their counterpart in the male. The micro-chromosomes are 44 in number like those found at the spermatogonial metaphase.

The nucleus in the resting phase contains a single, large deeply-stained heteropycnotic mass, from which radiate extremely fine threads (Fig. 3).

Meiosis :

The leptotene nucleus (Fig. 4) exhibits fine and faintly stained chromosomes threads apparently running into one another. Their exact number is difficult to determine owing to overcrowding of these faintly stained threads in a small nuclear space. The zygotene stage is of very short duration, and the actual pairing of the chromosomes is rather difficult to observe. Zygotene soon proceeds to pachytene. The pachytene chromosomes are thick, short and deeply stained (Fig. 5). They can be easily counted. The heteropycnotic mass referred to above lies excentrically. At diptotene the two largest autosomal bivalants have 5 and 4 chiasmata respectively and in the remaining bivalants the number of chiasmata vary from 1–2, depending upon the length of the chromosomes. At diakinesis the chromosomes undergo no change except that they are more condensed than the diplotene chromosomes, and the sex-chromosomes are indistinguishable from the autosomes, as they no more assume the form of a heteropycnotic mass (Fig. 7). At prometaphase the chiasmata exhibit different stages of terminalization, *i.e.*, in some of the bivalents they are completely terminalized. whereas in others they are only ring-shaped (Fig. 8.).

At the primary spermatocyte metaphase plate the chromosomal tetrads are dumb-bell-shaped and are of various sizes. The polar view (Fig. 9) shows 30 well defined elements which consist of 9 macro- and 21 micro-chromosomes. Out of the 9 macro-chromosomes, two are considerably large, 4 are medium and the remaining three are small in size. A large bivalent represents the sex bivalent and can be differentiated from the autosomes.

During the first spermatocytic division the homologues of the bivalents separate and move in the opposite poles of the spindle. The two largest chromosomes are however delayed in reaching their respective poles. It is difficult to count the exact number of chromosomes at the two poles of the spindle, mainly

on account of their overcrowding. In spite of these difficulties, there do exist some plates in which it is possible to determine the exact number of chromosomes after careful examination. Each pole at the end of the first anaphase is found to show 30 chromosomes. Here again the sex-chromosomes are indistinguishable from the autosomes (Fig. 10).

Interkinesis is of a long duration and is followed by the second metaphase stage. In the polar view of the second metaphase, there is usually overlapping of the chromosomes. In one of the best preparation (Fig. 11), 30 elements can be clearly observed. The two groups of macro- and micro-chromosomes are distinctly seen, the former lying towards the periphery and the latter occupying a central position.

In the second spermatocytic division, the chromosomes divide equationally and the divided halves pass to the opposite poles. At this stage it is possible to count the exact number of chromosomes in the daughter garniture. Besides the tiny size of the chromosomes their clumping together adds to the observational difficulties. The author, however, has not been able to count the exact number of chromosomes at each pole of the second anaphase.

The chromosome counts at the various stages of meiosis and mitosis are as follows :

Spermatogonial metaphase	..	58A + X + X =60
First metaphase	..	30 (bivalents) =30
First anaphase	..	30 (univalents) =30
	..	30 (univalents) =30
Second metaphase	..	30 (univalents) =30
Oogonial metaphase	..	58A + X =59

Discussion :

In *Streptopelia tranquebarica* it has been found that the sex-chromosomes lie as a fused heteropycnotic mass during the early prophase stage in the male meiosis. Many workers dealing with the different materials have reported the sex-chromosomes to be highly positively heteropycnotic in males and showing no signs of consideration in females (Stevens 1905 and 1909 and Smith 1952) the author is not in a position to generalise this statement for birds owing to the insufficiency of data. In reptiles too, which is the other member of the Sauropsida, Nakamura (1928, 1931 and 1932) reported the sex-chromosomes showing positive heteropycnosis.

In *S. tranquebarica* it has been found that the largest V-shoped chromosome is the sex-chromosome, as it is in the unpaired condition in the females. Thus the sex-determining mechanism in the species is XX male : XO female type. In *S. tranquebarica* the author, for the first time, came across the phenomenon of non-homologous association of chromosomes during prophase stage of meiosis. The heteropychnotic ends of the chromosomes are seen to fuse to form an irregular Feulgen positive mass. Such a clumping is sometimes observed at the periphery touching the nuclear membrane, which may be due to attraction between the nuclear membrane and the heterochromatic elements. In view of the well known act that the protein frame work of the heterochromatic regions of the chromosomes are different from those of euchromatic chromosomes or chromosome segments (Casperson 1941), it seems probable that the nucleo-protein matrix synthesized by heteropycnotic chromosomes is cohesive in nature (Schrader, 1941), and as such results in clumping. Prokofieva (1935) believe that all the heteropycnotic

chromosomes or chromosomal regions are homologous being genetically inert. According to him it is the attraction mainly responsible for the non-homologous association of chromosomes. This view gets further strength from the observations of Slack (1938) on spermatogenesis of *Corixa punctatis*. Schultz (1936), Thomas and Revell (1946), Bose (1948) and Ray-Chudhuri and Manna (1950) are of openion that apart from other causes the property of heterochromatic attraction is the main cause for such associations. The author also feels inclined to support the heterochromatin attraction hypothesis.

In the present study it has heen found that the first anaphase division the two largest chromosomes are always seen lagging behind a little distance, while the other chromosomes are proceeding to their respective poles of the spindle. According to Darlington (1937) there is a repulsion force operating between two poles which is responsible for the regular congression of the chromosomes on the metaphase plate. Oguma (1927) while studying the chromosomes of pigeon, reported that the largest chromosomes are often slow in their movement to the respective poles, whereas all the remaining smaller ones reach the poles earlier. He states "The phenomenon seems to be due to the weight and the magnitude of the chromatic substance, of which the chromosomes are composed, the small and lighter ones usually moving much sooner than the larger and the heavier ones". White (1932) also reported the occurence of this phenomenon in chicken and stated that the largest ones lag on the spindle, but all of them eventually divide. The author substantiates this statement as she too has observed that the largest chromosomes always lag behind. The overcrowding of the chromosomes on the plate has also been considered as one of the causes for the chromosomes lying off the plate (Koller and Darlington, 1934).

Summary :

The diploid chromosome number in the male and female of *Streptopelia tranquebarica* is 60 and 59 respectively.

The largest V-shaped chromosome is the sex-chromosome and the sex-determining mechanism is XX : XO type.

Phenomenon of heteropycnosis and non-homologous association of chromosomes has been observed.

First and second metaphase plate show 30 bivalent and univalent chromosomes respectively.

The largest pair of chromosomes, identified as the sex-chromosomes, show lagging behaviour at first anaphase.

Acknowledgement ;

The present investigations were carried out in the Zoological Laboratories of Allahabad University under the guidance of Prof. M. D. L. Srivastava, to whom the author is indebted for permission of work, suggesting the problem and for various other helps. The author is also indebted to the Director, Zoological Survey of India for the identification of species. The author expresses her sincerest gratitude to Dr. Krishna Swarup, for many helps received at his hands.

References :

Bose, I. The association of the non-homologous chromosomes in the spermetogenesis of the lady bird beetle *Epilachna vigintioctopunctata*. *Zool. Soc.* Bengal, **1** : 131–139, 1948.

Capersson, T. Studien uber den Eiweissumsatz der Zella. *Naturwissenschaften*, **29** : 33–34, 1941.

Darlington, C. D. Recent advances in Cytology. London, *Churchill*, 1937.

Koller, P. C. and Darlington, C. D. The genitical and mechanical properties of the sex-chromosomes of *Rattus norvegicus* male. *Jour. Genet.*, **29** : 159–173, 1934.

Nakamura, K. On the chromosomes of a snake, *Natrix tigrina*. *Mem. Col. Sci.* Kvote, Ser. V, **4** : 1–8, 1928.

——— Studies on the reptilian chromosomes. II. Chromosomes of a lizard *Eumeces latiseutatus* (Hallowell). *Cytologia*, Tokyo, **2** : 285–401, 1931.

——— Studies on reptilian chromosomes. III. Chromosomes of some Geckos. *Cytologia*, Tokyo, **3** : 156–168, 1932.

Oguma, K. Studies on the Sauropsid chromosomes. I. The sexual difference of the chromosomes in the pegion. *Jour. Coll. Agri.* Sapporo, **16** : 203–227, 1927.

Prokofieva, A. A. Structure of chromocentre. *C. R. Acad. Sci.*, USSR. **2** : 498, 1935.

Ray-Chudhuri, S. P. and Manna, G. K. On the frequency of association between non-homologuous chromosomes in the grass hopper *Gesonia punctifrons*. *Journ. Expt. Zool.*, **2** : 421–443, 1950.

Schrader, F. Heteropycnosis and non-homologous association of chromosomes in *Edessa irrorata* (Hemiptera, Heteroptera). *Jour. Morph.*, **69** : 587–604, 1941.

Schultz, J. Variegation in Drosophila and the inert chromosome regions. *Proc. Nat. Acad. Sci. Wash.*, **22** : 27–33, 1936.

Slack, H. D. The association of the non-homologous chromosomes in corixidae (Hemiptera, Heteroptera). *Proc. Roy. Soc.* Edin., **58** : 192–212, 1938.

Smith, S. C. The evolution of heterochromatin in the genus Tribolium (Tenebrionidae, Coleoptera). *Chromosoma*, **4** : 585–610, 1952.

Stevens, N. M. Studies in spermatogenasis, with special reference to the "accessory chromosomes,'. *Carneg. Inst.* Wash., **36** : 3–32, 1905.

——— Further studies on the chromosomes of Coleoptera. *Journ. Expt. Zool.*, **6** : 101–121, 1909.

Thomas, P. T. and Revell, S. H. Secondary association and heterochromatic attraction I. *Cicer arietium*. *Ann. Bot.*, **10** : 150–164, 1946.

White, M. J. D. Chromosomes of domestic chick. *Jour. Genetics*, **26** : 345–350, 1932.